May

Final Examination of the Senior Class of 1848 and 1849

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|---|---|---|
| 8 Tuesday A.M. | Locke; Logic; Mor. Philos; Evidences; | Rhetoric; Nat. Theology; English Grammar |
| " P.M. | " " " " | " " " |
| 9 Wednesday A.M. | " " " " | " " " |
| " P.M. | " " " " | " " " |
| 10 Thursday A.M. | Chemistry | Geography |
| " P.M. | " | " |
| 11 Friday A.M. | Greek | Astronomy |
| " P.M. | " | " |
| 12 Saturday A.M. | Geometry | " |
| " P.M. | " | Algebra. |
| Monday A.M. | Nat. Philosophy | Latin |
| " P.M. | " | " |

Geo. E. Clymer

Rec[illegible] D. North College.

Notes of Lectures delivered on Natural Philosophy
to the Senior Class of 1848 & '49
by
Professor Elias Loomis
Written by
Geo. E. Clymer
Recess D. North College
Nassau Hall
Princeton
New Jersey

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Lecture 24th Second Course.. Senior Class of 1849

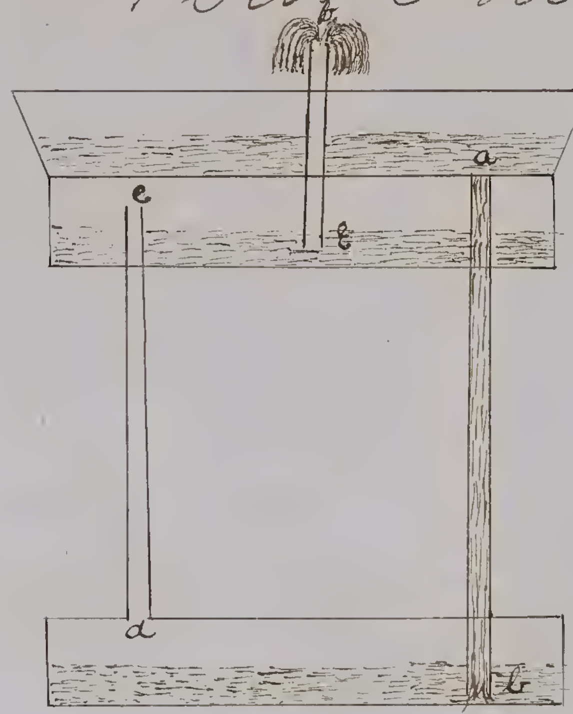
It will be remembered that mention was made, during the course of Lectures last Session, of the composition of forces. It was laid down as a general principle that if two forces be represented by two sides of a triangle, their resultant force will be represented by the third side.

This principle is also true when applied to motion although the forces made use of to represent motion were weights.

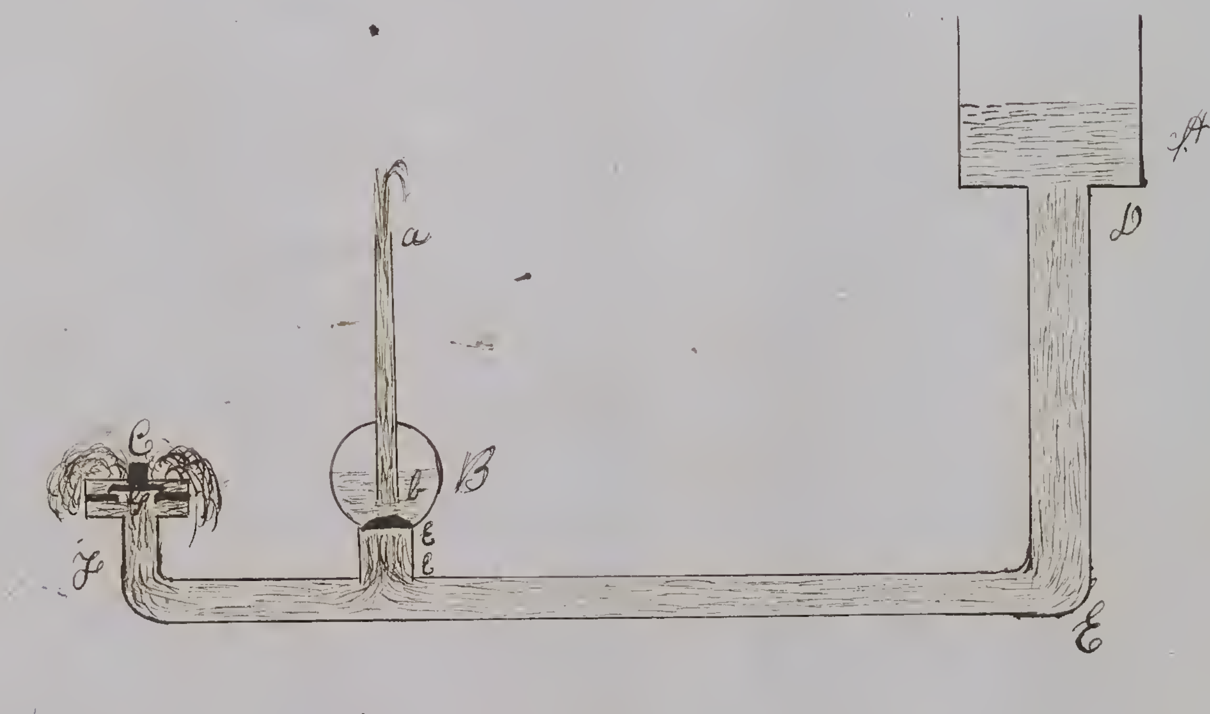
Suppose, for the sake of illustration, we have a square board, in one corner of which are two pillars, or rods to which are attached two balls of equal size and weight, that move freely up and down these rods. Now if a ball be placed a the bottom of one of these rods & the ball on the rod be allowed to fall on the other ball, it will move in a line parallel with the sides of the square; the result will be the same with the other ball; but if both balls be allowed to fall at the same instant the lower ball will move in a diagonal direction.

It may also be shown by peculiar arrangements that the pressure of liquids upon the bottom of a vessel depends upon the height and not of the amount of fluid. Suppose that we have a bent tube filled with mercury, and to one end of

Hero's Fountain




Hydraulic Ram.



which may be attached different vessels. Now if we attach different containing various quantities of water but of the same height, we shall in every case find that the mercury has risen to the same height in the opposite arm.

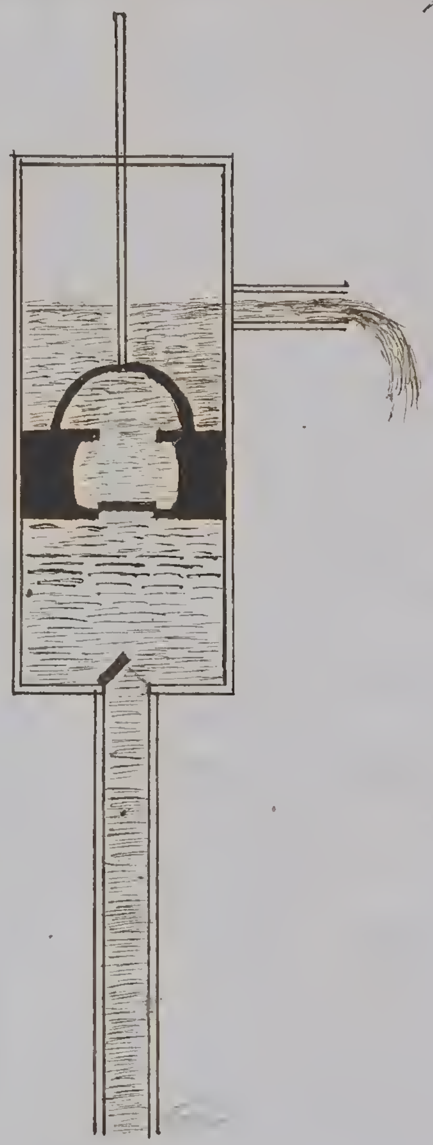
The Elasticity and Pressure of the external air both illustrated by what is commonly called the Bolthead experiment, which consists of a glass globe with a tube immersed in water ~~and~~ which is placed in a receiver; when extract the air from the receiver, the air in the bolthead expands and rises in the water, until it is nearly entirely extracted; when the air is admitted into the receiver, the water in the vessel rises in the bolthead. This same principle is exhibited in Hero's Fountain. It is composed of two close vessels one placed above the other, both filled partly with water and partly with air; the upper nearly entirely with water and the lower nearly entirely with air. There is a tube from the top of the lower vessel to very near the top of the upper one; there is another tube from the very nearly the bottom of the lower vessel to the basin; there is still another tube running from the bottom of upper vessel and projecting some distance above the basin, through this latter tube the jet passes.

Now if water be poured into the reservoir, it will descend through the tube 'a b' and partly fill the lower vessel. The air in this vessel escapes through the tube 'c d' into the upper vessel, where it is again compressed, and by means of its elasticity forces the water of the upper vessel through the small tube 'e f' in a continuous jet until the upper vessel is nearly empty or the lower vessel nearly filled with water. At the commencement of the experiment the lower was filled with air and the upper one with water. The force which produces the jet is equal to the pressure of a column of water, whose height is equal to the difference of the level of the water in the basin & the lower vessel, according to theory, then, the water should spout to a height above its level in the reservoir, equal to that distance.

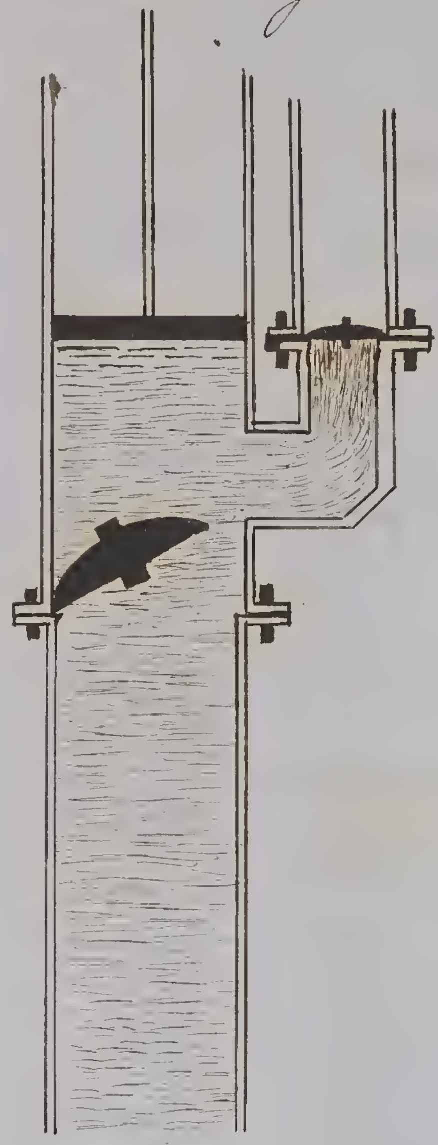
The Hydraulic Ram is an apparatus used for the purpose of raising water above its source by its own force. It is made in this manner; there is the reservoir A from whence it is desired to raise the water a certain distance; there is a pipe D E F with a slight inclination downwards through which the water passes from A; there is also a globe B, partly filled with water and air, with a valve opening inwards; there is also at the end of the pipe D E F an opening,

C, through which the waste water escapes, and which by the force of the water is closed by means of the stopper G. The water from the reservoir passing through the pipe DEF with a velocity equal to the fall escapes through the opening, C, this can be closed by the stopper, G. When the water is prevented from escaping from the opening, C, by the stopper, G, this opening is closed by the velocity of the water. When the opening, C, is closed, the water raises the valve, opening into the reservoir B, and a portion of the water, (about one fourth) is introduced into the reservoir and into the pipe, ab. By this operation it looses the velocity it possessed when the opening at C was shut, and both valves again resume their former positions. The water a second time begins to flow through C and the valve at the reservoir B, is closed. The same operations are performed in very short intervals of time, and at every ~~im~~ impulse a fresh quantity of water is forced into the reservoir. B. By means of the elasticity of the air contained in the reservoir, B, the water is forced through the pipe, ab, to the desired height, because it is prevented from escaping through the other opening by the valve at the bottom of reservoir. By means of the Hydraulic Ram, ~~may~~ water may raised to a height of 60 feet by a very small force.

Suction Pump.

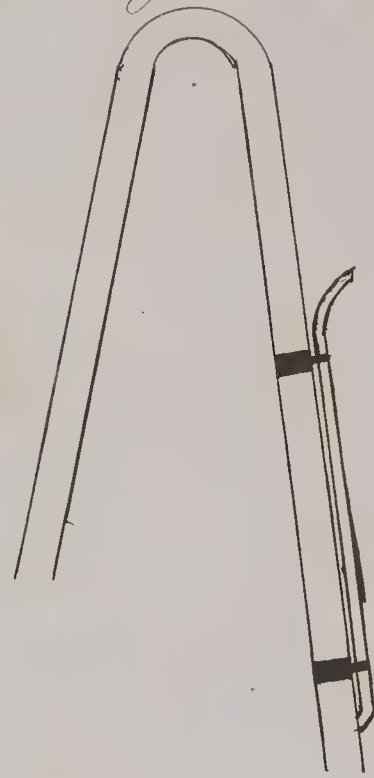


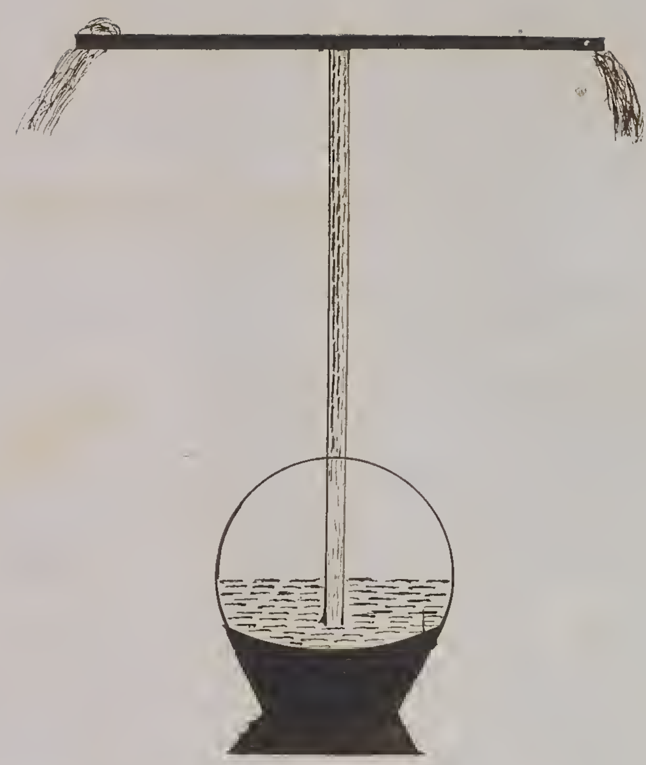
Forcing Pump.



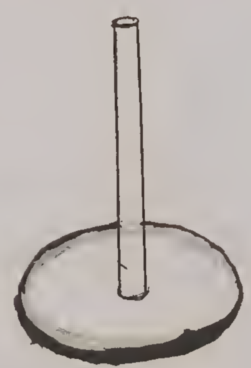
The Suction Pump consists of a hollow cylinder in which a piston works. At the bottom of the cylinder is a valve and another in the piston, both opening upward. To the end of the cylinder is attached a pipe, which reaches below the surface of the water in the well. When the piston is raised, the air in the cylinder expands ~~between the valves~~, and its tension diminishes, and the pressure of the air in the pipe opens the valve at the bottom of the cylinder, and the air becomes less dense. The atmospheric pressure forces the water to rise in the pipe, until the tension of the confined air is equal to the atmospheric pressure. The piston again descending, the valve in it opens and the air passes through it from the cylinder, as it descends, but the lower valve being closed by the downward pressure ~~[illegible]~~ ~~so~~ the water remains. In raising the piston the same effect is repeated & some more water enters the pipe. Thus a column of water is raised in the pipe, until it reaches the piston when at the bottom of the cylinder & all the air has been excluded. In raising the piston the water follows and when it again descends the water passes through the valve of the piston and when the piston is raised, the water pours through the spout. The forcing Pump differs from the Suction Pump in that it has no valve in the piston, the water being forced up through a tube at the side of the cylinder to the height required.

Suction Syphon





Pneumatic Paradox.



Lecture 25th

There is another description of Syphon, which we have not mentioned. It consists of a small tube, that runs along the outside of the long arm of the Syphon, on the outside, and is inserted in the tube near the extremity; it is called a suction tube. By the means of this tube, the air may be exhausted and the liquid is made to flow, without any inconvenience of taking any portion of the liquid in the mouth. This arrangement is peculiarly convenient when it is desired to draw acids.

It has been previously shown that motion is produced by removing the pressure from one side of a horizontal bar. By condensing the air in a globe, containing water, we can force the water through an upright tube into a horizontal arm. If there is a small opening near the extremity of the arm, through which the water may escape, the unbalanced pressure on the one side will cause the arm to revolve, in a direction opposite to that in which the water flows. The motion will be twice as much, if there is another opening at the extremity of the opposite cross-piece.

The Pneumatic Paradox is a strange phenomenon, and is caused by impelling a current of air against a card, which instead being blown off is held firmer. The Pneumatic Paradox consists of a circ-

cular disc, perforated in the centre with a hole, through which a tube passes. By attaching a card to the surface of the disc and blowing through the tube, the card is firmly held to the surface of the disc. The paradox consists in the fact that the harder we blow, the more firmly is the card attached, and against the power of gravity. There are numerous explanations for this fact:

1st That when we blow through the tube, the air issuing between the card + disc, produces a counter current beneath the card, that hold it in its place. There may be some such current, but it is not sufficient to sustain the card, as is shown by the following experiment. We take a a glass vessel, cover the mouth with a card, with a circular opening, just large enough to a admit a long paper cylinder, substituting the head of this cylinder, for the card, and blowing upon it, it will adhere to the disc, not how ever by means of the counter current, because the cylinder was in a closed glass vessel.

2nd That the air between the disc and card is is rarified by the heat of the lungs, and that the excess of pressure on the lower side presses it against the disc. This is not true, because if bellows are substituted, the same effect is produced.

3rd Instead of a card we have a disc with several small tubes attached to the lower side, and we plunge them in vessel containing water. If we now blow through the tube, the water rises in the tubes, proving that the air in them was rarified, and it is the excess of pressure on the lower side holds the card. Now what produces this rarifaction. In a former lecture we noted the difference between the pressure of fluid at rest and fluid in motion; it was demonstrated that in the case of a fluid passing through a tube the pressure was diminished, and that there was certain point when the fluid exerted no pressure. The same thing is true of air; it exerts less lateral pressure when in motion than at rest. When we blow through the tube, the air passes out between the two surfaces so rapidly that it does not exert much lateral pressure and the atmospheric pressure beneath the card support it.

We now come to the subject of Acoustics. Acoustics treats of the nature and laws of Sound. The immediate cause of sound is the vibrations in the sounding body. In musical strings the vibrations are apparent to the eye. When a bell is supported in such a way that we can move a metallic point gradually up to it,

when struck produces a rattling noise. When these these vibrations are not sensible to the eye, they can be made so by the some mechanical contrivance. Sound therefore will not pass through void space; there must be some medium for conveying the sound. The ordinary medium for the transmission of sound is the Air. No sound proceeds from a bell when struck in an exhausted Receiver. No Sound therefore can reach us from beyond the limits of our atmosphere. Sound requires time for its propagation. When we notice the flash of a gun at a distance, after a short interval we hear the report, and the length of the interval is in proportion to the distance. The velocity of sound has been determined by the following experiment. In the night time a gun was fired at a preconcerted time, and a party, some miles distant, observed the ~~exact~~ time of the flash and also of the report. There is this source of error to be guarded against, the Air may itself be in motion, and retard or accelerate the velocity. This error may be avoided by firing a gun at the second station and making the same observation. If the air is entirely at rest the result will be the same, if in motion, the velocity in one instance ought to be added in the other subtracted. The true result will be the mean of

two intervals. Numerous experiments have been made at different temperatures. At a temperature of 32° the velocity of sound is 1090 feet per second, and it increases $1\frac{14}{100}$ for each degree above 32°. Knowing now the velocity of sound ~~we~~ we may easily calculate, tolerably accurately the distance of a sounding body. By this means we can calculate the distance of a Thunder Cloud. We commonly say that sound travels a mile in 5 seconds; thus we have only to calculate the interval of time between the flash and report. Sounds of every Pitch and Quality travel with the same velocity, This is proved by the performance of a piece of Music, at a distance; every note is heard and at the proper time.

Liquids & Solids convey sound much better than gasses. The velocity of sound in water has been determined by experiments. A bell fastened to the stern of Boat was immersed, and at a certain distance, there was a tube, like an ear-trumpet was plunged upright in the water. When the Bell was struck a flash of powder gave notice to those at the tube. The result of this experiment was that sound traveled in water at the rate of 4708 feet per second. The velocity of sound in cast-iron is 11000 feet per second. This was proved by means of the water-pipes of Paris. It follows from this that if we have a long iron tube and strike it a small blow at one end, there will be a certain interval before the

sound reaches the other end. If we had a rod extending from the Earth to the Sun, and strike it a blow at one end it would be nearly two years before it could reach the other end. Sound is reflected by the same laws as those of heat & light. To prove this we employ two parabolic metallic mirrors, so arranged that their foci are exactly opposite; if we place a watch in the focus of one mirror, a person with his ear in the focus of the other will distinctly hear the ticking. When sound is reflected from a smooth wall, there is an echo. If the walls are distant 62 feet, the sound going and returning will pass over 124 feet, which would require about the 1/9 of a second. This is about as small an interval as the ear can perceive. If the distance is less the words will blend together with the original voice. If the distance is greater we can perceive an Echo of 2 or 3 syllables. There are certain situations where there are echos of 15 or more syllables.

A wave is not a progressive moving body but an advancing form. If a cord, tightly stretched across a room, is struck, at one end, we see something moving rapidly from end to end. Nothing really moves along the rope; it is simply the motion of the particles up and down. The following apparatus is designed to show this motion; it consists of several vertical rods arranged in a frame parallel to each other; to the upper ends of these rods are attached small Balls, and the lower ends are fastened to circular plates whose centres are

eccentric, and through these centres passes an axle, turned by a crank. By turning this crank, these rods are moved up and down, illustrating the motion of the particles of the rope; the balls do not move along like a progressive moving body, but is simply an advancing form. When an elastic body is made to vibrate, the particles of which it is compound are alternately compressed and rarified. Air has actually been rarified five thousan five hundred and eighty times, and has actually been condensed fifteen hundred time more than the density of common air. It has been obtained eight millions of time denser than the rarest. In both these extremes air retains its Elasticity. These experiments go to prove that the particles do not touch each other, but are comparatively separated from each at an immense distance.

# Lecture 26th Feb 15th 1849.

In the last Lecture it was stated that solid bodies convey sound. This is shown by the following experiments. Two Guitars are placed in different rooms, and connected by a rod of wood or any other solid substance; now if some person plays upon one of the guitars, the sound will be conveyed along the rod, and be distinctly heard in the next room, proceeding from the guitar. Musical sounds are caused by vibrations occurring at equal intervals; there must, also, be a certain rapidity in these vibrations. If the vibrations are less than 32 per second, no musical sound is heard. If we make a string to vibrate, if slightly stretched, scarcely any sound is heard. There is also a certain limit beyond which no musical sound is heard, viz; 12000 vibrations per second. Between these two extremes all the musical sounds are produced. The most rapid vibration is 400 times the least. Now there must be some mechanical means to calculate the vibrations, as they are too rapid for the eye to perceive. The Acoustic Syren is designed for this purpose. It consists of a tube, through which air may be impelled, which passes through 25 small orifices, arranged in a circle; directly over this plate is another circular plate, having as many orifices, so that the orifices of the two plates exactly correspond. These orifices perforate the plate in oblique direction, and the air issuing from them causes the

upper plate to revolve, the lower one being stationary. The air, by means of the revolutions, is alternately interrupted and transmitted, and causes vibrations, which if sufficiently rapid will produce musical sounds; any musical note can be sounded by regulating the current of air. To measure these vibrations the operation is thus; to the axis of the upper plate is attached an endless screw, turning a wheel, having an index. This wheel acts upon a second wheel, one whole revolution of the first wheel causing the second wheel to advance one point. The second wheel has an index, which registers the number of vibrations on a dial. If we wish to determine the number of vibrations, we blow through the tube, until the desired is sounded; the number of revolutions are registered upon the dial, and with a watch the number of vibrations per second can be determined.

Musical Sounds differ in three particulars Intensity Pitch and Quality. The intensity depends simply upon the extent of the vibrations. When the vibrating arc is small the sound is low, when large it is loud. The intensity does not affect the Pitch. The Pitch depends upon the frequency. The Quality depends upon the nature of the vibrating body. Many instruments may have the same pitch, but a practised ear can easily tell from what instrument they proceed. A cord or glass rod may vibrate either laterally or longitudinally. All the vibrations of a cord like a pendulum are isochronous, and this is true whether

they vibrate through large or small arcs. A string may be made to vibrate as a whole or in parts. A vibrating chord may spontaneously divide itself into any number of parts, each of which will vibrate separately, as if it formed a separate chord. It therefore performs its vibrations as much more rapidly as it is a smaller aliquot part. The chord A B may divide itself into any number of equal parts, as 2, 3. or 4, at different points ~~at~~ each of which will vibrate 2 3 or 4 times more rapidly than the whole chord, and in such a manner that the adjacent parts will be in opposite phases, at the same time, while the points of division remain fixed. These points are called Nodes. These different vibrations may coexist; thus a musical string will produce not only the key note, but at the same time a series of sounds agreeing to the number of vibrations of chords 1/2 1/3 1/4 &c in length. The length of the string being called 1, the respective lengths of the strings that sound the octave are 8/9, 4/5, 3/4, 2/3, 3/5 8/15 & 1/2. The sound of the whole string is called the key note. The vibration of a Tuning fork is as follows. By force we compel the two prongs to separate, their elasticity brings them back, in this way they oscillate backward and forward

The A. tuning-fork makes 880 vibrations per Second. The Some say that a vibration must go from one side of the arc to the other side, and then back again to the first point. These are called double vibrations; according to this rule A only makes 440 vibrations per Second. The C tuning fork

makes 528 vibrations per second. We may have vibrations of glass plates or plates generally. Here instead of having nodal points we have nodal lines. These nodal lines are separate the vibrating parts of the plate. These lines remain at rest. These nodal lines may be shown by sprinkling sand on the plates. This method was first discovered by Galileo. When a plate is firmly fixed at its centre, between two points, the most simple nodes of vibration are two straight lines parallel with the sides of the plate, and intersecting each other at rightangles. The next most simple nodes are two straight lines crossing the plate diagonally. Almost any number of these nodal lines may be formed.

A Bell is to be regarded as an assemblage of rings all cemented together. Here there are nodal lines as in the plate. The gravest note that can be obtained from a bell consists of 4 vibrating segments. These two positions succeed each other rapidly in the 60th part of a second. The next gravest note consists of 6 nodal lines; the next of 8, the segment always being in even numbers.

The length of an undulation corresponding to any note may be shown by filling a glass vessel with water. The gravest note corresponds to about 32 vibrations per second. Sound travels 1142 feet per second; 1142 divided by 32 will give the length of a column of air, that will sound the gravest note.

# Lecture 27th

Two loud sounds may be made to produce silence; this results from the interference of vibrations. When we give a slight impulse to a stretched chord, a wave moves along the whole length; but the motion of the particles is simply up and down. We may by giving the chord another impulse produce another series of waves; now these two series of waves may meet in such a manner as to interfere. By superposing one wave upon another in ~~different~~ the same phases, we have a double wave. If they are superposed in such a manner in a manner that the elevation of one wave shall correspond to the depression of the other, there is an interference + we have no wave. These remarks also apply to the vibrations of a musical string or pipe. When two vibrations meet in the same phase, they are superposed and we have a vibration equal to the sum of both. When in opposite phases, the result will be the difference of the two. These interferences may be shown by experiment. By sounding two tuning forks, of different pitches, over a glass cylinder containing air, the waves of sound alternately interfere and coincide, producing a musical swell. These same interferences may be shown by an arrangement producing two notes differing slightly in pitch, i.e. Organ Pipes. The number of beats in a second shows the number of vi-

brations one sound gains on another in a second. The length of any note may be determined by the number of undulations. It requires pipes of different length to sound different notes. The common organ pipe is nothing but a mere whistle. There are certain attachments for the purpose of modifying the sound; they are called reeds and are of two kinds. The first is the common reed; it consists of a tube through which a column of air passes; there is a small orifice on one side, which alternately opens & closes. The intensity of the sound depends on the rapidity of the interruptions. The second variety consists of a tube like the first, and has an opening in a metallic plate; this opening is closed by a thin metallic plate, and when this is bound down closes the opening almost exactly. The sound is reinforced in a tube attached to the reed. In these tubes the pitch depends upon the number of vibrations of the plate, so that with a tube of given length we may get several notes. The organs of voice in man consist 1st of the Lungs placed near the Thorax; 2nd of the Thorax; 3rd of the Trachea, through which the air is impelled by the lungs. 4th of the Larynx placed at the upper end of the Trachea, in which are placed the most essential parts of the organ of voice; viz; the Glottis placed a little below the Palate. This ~~cavity~~ is formed of two chords.

called the upper and lower vocal chords. By the stretching of these two chords this tube is nearly closed. The Chords and cavities are chiefly instrumental in producing sound. What has been considered as the greatest difficulty of explaining the human voice, is the variety of different notes obtained from the same tube. From an organ pipe we obtain but one note, but with this tube we obtain a variety of notes running through two or three octaves; it, however, sounds every intermediate note. The instrument that comes nearest the human voice, is the common whistle or bird-call. The cause of the sound produced by this instrument is this: when you blow through the orifice, the rapid flow of air carries along a portion of the air contained in the cylinder. This creates a partial vacuum & immediately the air is forced back by the external pressure. The same operation takes place the next instant and succeed each other very rapidly. This rapidity depends upon the velocity of the blast, thus by varying the velocity we vary the sound.

## — Heat —

We shall now speak of Heat. All bodies are expanded by heat. It is known by the followin arrangement. We have a rod of iron or any other metal supported at its extremities upon two points, one of these extremities presses against a lever, to which is

attached an index. By heating the rod, its length is increased, and is shown by the index on a dial that is graduated. Thus the expansion of metals may be easily shown. Different substances expand differently by heat. Iron expands 70 parts in 10.00000 for one degree of Fahrenheit. Copper expands 94 parts in 10,000000. Brass 95 parts in 10,00000. Liquids expand as well as solids. If we have a glass globe, filled with water, and having a straight tube attached, to it, by applying the heat of a spirit lamp the water will rise in the tube. Air, likewise, expands by the application of heat. Suppose we have a glass retort filled almost full of water, and plunge the open end in a vessel with water in it, by applying heat the air in the water will expand and rise to the surface. The magnitude of all objects depends upon their temperature. A scale which is a yard long in summer, is less than a yard in winter; a vessel which holds a gallon in summer will not do so in winter. An instrument for the purpose of measuring heat is called a Thermometer. They may be made either of Solids, Liquids or Gasses. Mercury is, however, commonly used. It is used 1st because, it supports more heat than almost any other fluid, before it boil or passes into vapor, and supports more cold than other fluids, except certain spirituous liquors; 2nd Because the varia-

tion of its volume, is perfectly regular with the variations of temperature. Its construction is as follows. We take a capillary glass tube of a uniform diameter; we then blow a bulb upon one end. As the bore is very small we can not pour the mercury into the bulb; we must therefore use artifice to effect it. It is usual to expel a portion of the air by heating the bulb, the open end is then immersed in mercury, and as the air cools, the mercury rises in the tube. By again applying the flame, and causing the mercury to boil, the remaining air is readily expelled, and its place supplied by mercurial vapour; it is again immersed in mercury, which rises when the tube becomes cool. When the tube has in it the proper quantity of mercury, and all the air expelled, the thermometer is hermetically sealed. The instrument is then prepared to be graduated. Two points must always be determined to graduate an Thermometer; they are boiling water and melting ice; they have been universally agreed upon. These points have been chosen because they are invariable. According to Fahrenheit's Thermometer the boiling point is fixed at 212°; and that of melting ice at 32°; their interval is divided into 180°. To find these two points the instrument is first placed in boiling water and then in melting ice, and the

two points where the mercury stands are marked with a file. The Centigrade is another method of graduation. The point of boiling water is fixed at 100°; that of melting ice at 0°; being divided into 100 equal parts. The scale is continued below 0° and is is marked −0°. Raumer's Thermometer fixes the boiling point at 80° and melting ice at 0°.

# Lecture 28th Feb 20th 1849

A Mercurial Thermometer upon Fahrenheit's scale is never graduated lower than $-40°$; it may, however extend upward indefinitely. Mercury freezes at at $-39°$; hence it cannot be used in temperatures below that point. For indicating lower temperatures some other substance must be used, it is generally Alcohol. Pure Alcohol has never been congealed by any natural temperature of nature; although a temperature of $80°$ below zero has been actually observed in the Polar regions. Air is often used for thermometers, as it expands easily by increase of heat. If heat be applied to a retort, filled with common air, and plunged in water, most of the air is expelled. When the retort is allowed to cool, the air returns to its original state, the water will rise in the retort and take the place of the expelled air. Air thus readily indicates very slight changes in temperature; in solids we can only make this expansion sensible by artifice. Air is therefore a very suitable substance for thermometers; there is, however, one inconvenience, it is affected by pressure as well as heat. It is therefore a Barometer as well as a Thermometer. Air is most conveniently employed for a differential thermometer, i.e; for indicating the differences in Temperature. The Differential Thermometer of Leslie consists

of two glass united by a bent stem. Both bulbs are filled with air, but the middle of the tube is filled with Alcohol. If we heat one of the bulbs, air will expand, and cause the alcohol to move in the opposite direction. An arbitrary scale is attached, for the purpose of indicating differences of temperature. This Thermometer is designed to indicate the difference of temperature in the two bulbs. There is also another apparatus called the Thermoscope of Rumford. It consists of two glass bulbs connected by a stem; at one side of the tube there is a small reservoir con= alcohol, by means of which a large or small quantity be admitted at pleasure. One of the bulbs is blacken=ed, in order to make it more sensitive, a black bulb absorbing heat better than any other. All thermometers are imperfect, since no two substances expand alike exactly. The expansion cannot therefore be proportioned to the temperature; for example, one degree of heat applied at 400° produces a greater degree of expansion than if applied at 100°. The Mercurial Thermometer answers very well up to 212°; above that, the air thermometer is more to be depended on. The different expansion of metals can be shown by the following experiment. If we take two straight strips of different metals & solder them together, we may have a straight line at a certain temperature, but at any other they will be curved.

Brass and Iron expand unequally. If then we unite two bars of brass and iron, the brass uppermost; by then applying heat the brass portion will be longest; but if we cool them artificially, the iron will be the longer. Silver and Platina will produce the same effect; the expansion of silver being twice that of platina. This principle of expansion of metals has been applied to the construction of a thermometer. A strip of this compound metal, silver and platinum, is wound into a coil; the silver being on the outside, as it is the most expansible, when heat is applied the effect will be to give an increase of coil. If an index is attached to the end of the coil, it will move, and the temperature will be indicated by means of a dial. It is called the metallic Thermometer of M. Breguet, and is an exceedingly delicate instrument. For measuring very elevated temperatures, some different arrangement is required. Wedgewood's Pyrometer is such an instrument. It consists of a bar of metal or porcelain, which has a groove that converges. A small cylinder of clay is made to fit exactly the large end of the groove. Clay contracts by heat, forming an apparent to the general Law, but it is only apparent, the contraction being due to the expulsion of the moisture. There is an index, attached, which is graduated from 0° to 240°. Each degree of Wedgewood

is equal to 130° of Fahrenheit. When the pyrometer is placed in a furnace; the clay will shrink and slip down to a certain point, which indicates the tempera=ture. The thermometer does not indicate the quantity of heat present in a body, only its intensity. Two bodies may contain very different quantities of heat, even when the temperature is the same. When a body is heated above the temperature of surrounding bodies, it looses heat in two ways, viz; by radiation and conduc=tion. All bodies radiate heat from the surface; this is illustrated by the following experiment. We have two parabolic mirrors, their being exactly opposite to each other. If a heated body be placed in the focus of one mirror, the rays will be reflected from one parallel lines, which falling upon the opposite mirror will ~~be~~ reflect and collect in a single point at the focus. If a piece of phosphorus be placed in the focus of the oppo=site mirror it will be ignited. This demonstrates several principles. 1st That heat is radiated; 2nd that heat is reflected by the same laws as those of light. i.e; the angle of reflection is equal to the angle of incidence. This is proved by the fact, that the phosphorus was fixed behind a piece of cork, cut away on one side. Here is another arrangement for exhibiting the ref=lexion of heat and the difference of the reflective pow=ers in different bodies. It consists of a cubical tin

canister, each of whose sides is covered with a different substance or metal, one side being polished, a second being rough, a third covered with lamp-black &c. This vessel is filled with water kept continually at a certain temperature. It now radiates heat, and each of its sides is presented in succession to a parabolic mirror, having in its focus ~~one~~ the blackened bulb of a differential thermometer. Having observed ~~the~~ the effect when one surface is presented, we turn it round and observe the of the others. The different effects produced on the thermometer, ~~are~~ taken as measures of the comparative radiating powers of the different surfaces. In general then we find that rough surfaces radiate heat more rapidly than smooth ones.
When one end of a metallic bar is held in the flame of a lamp, the other end is presently heated; the end in the flame is heated and conveys the particles of heat to the other end. This is called Conduction. If we heat a small piece of charcoal in the same manner one end is ignited, while ~~the~~ the other does not feel warm. We find then that different substances conduct heat very differently. Conduction may be shown by the following experiment. Take a strip of copper and place small pieces of phosphorus on it at different distances, by placing one end in a lamp the rate of conduction will be shown by the times the ignition of the phosphorus occur.

we find that they ignite at certain intervals. The temperature at which phosphorus ignites is 46°. This not only shows that heat is conductive, but that it travels along progressively. There is another instrument better adapted for the purpose of measuring the conductive power of different substances. It consists of a long metallic bar perforated with circular holes, at certain distances, for the purpose of receiving the thermometer bulbs. By heating this bar at one end, the rate at which the heat travels is indicated by the thermometers. There is still another instrument for the same purpose. It consists of a square vessel filled with hot water, in the side of the vessel are inserted rods of different substances, whose conductive power is ~~to~~ are be measured. They are arranged in the order of their conductive powers; 1st Silver 2nd Copper, 3rd Brass, 4th Steel 5th Iron 6th Lime, 7th Zinc, 8th Glass 9th Wood. The bars are all of the same dimensions and coated with wax. The conductive powers of the different substances will be indicated, by the several times at which the wax melts from the several bars.

Lecture 29th Feb 22nd '49. Heat continued.
The following experiment is explained by some of the previous principle. In the first place let us take a wooden cylinder, with a strip of paper wound round it, and holding it over a flame, the paper is singed. If a iron cylinder, wrapped round with paper, and held over a flame, the paper will scarcely injured. These effect must be explained by the different conductive powers of the two substances. Wood being a bad conductor, nearly all the heat is absorbed by the paper; iron being a good conductor, most of the heat is conveyed away by the cylinder, and must be well heated before the paper burns. Solids in general are the best conductors; Liquids next; and Gasses the worst. Of solids metals are generally the best conductors, viz; Gold, Silver and Copper. Some of the worst are Charcoal, Ashes, Wool, Silk &c. When heat is applied to the bottom of a vessel containing water, currents are established. The heat is said to be propagated by convection. If heat is applied to the bottom of a vessel of water, the water at the bottom is heated first and being specifically lighter rises, thus heat is communicated to the whole. An upward current is formed in the middle, a downward one at the sides. Thus a regular circulation is kept up. If the water contains saw dust, the current are made visible. If water is taken at a temperature of 32° and warmed, instead of expanding

it contracts and continues to do so up to 39½°; after this it expands. If we take water at 38° 30′, it will expand, whether we cool or warm it. This then is called the maximum density of water. This is an apparent exception to the law that all bodies expand by heat; it however is only an apparent exception. Ice is a species of imperfect crystallization in which the particles assume definite positions, they therefore occupy more space, than they do in a liquid. This crystallization is considered to commence at 39½°. This is a principle of great importance in nature. When a mass of water cools in winter the colder particles descend; but after reaching 39½ the reverse takes place: the colder particles, below 39½° are the lighter and therefore float to the surface. If congelation commenced at the bottom nearly all rivers and lakes would become solid masses of ice. Now as the congelation takes place on the surface, the crust is in some measure a protection against further crystallization.

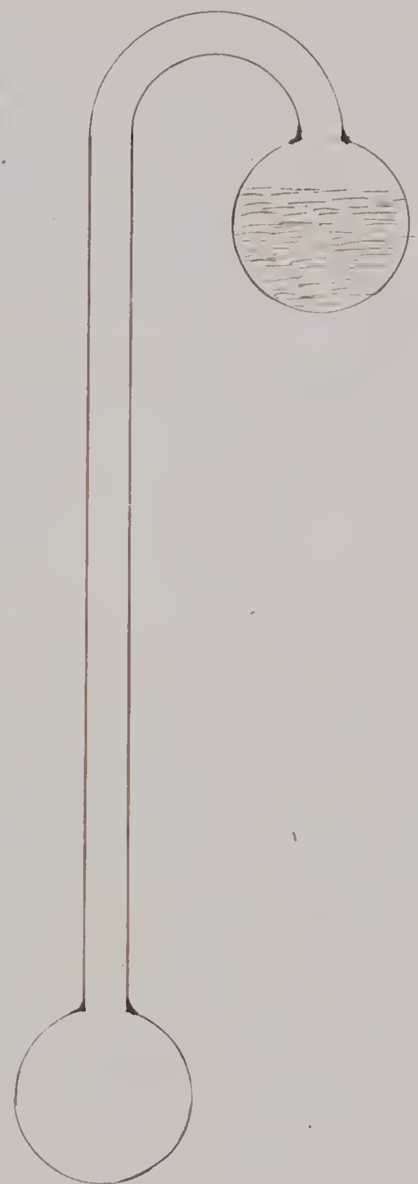
Capacity of Bodies for Heat.

Different bodies require different degrees of heat to warm them equally. This is the case with water & quick-silver. For example if we mix a pint of water at 40° degrees with a pint of ~~quicksilver~~ water at 100°; the temperature of the mixture will be 70°. But if we mix at pint of water at 40° with a pint of quicksilver at 100°; the temperature of the mixture will be 60°. That is the water has

gained 20° & the Mercury has lost 40°. Hence we say the capacity of water for heat is double that of Mercury. This is the case when we have equal volumes of both. But if we make the comparison by weight, its capacity is 23 times that of Mercury. If we take equal volumes of water and mercury, the temperature of the water being 48°, that of the mercury 141°; now if we mix them the temperature of the mixture will be 77°. Here the water has gained 29°, the mercury has lost 64; the loss of the mercury being little more than double.

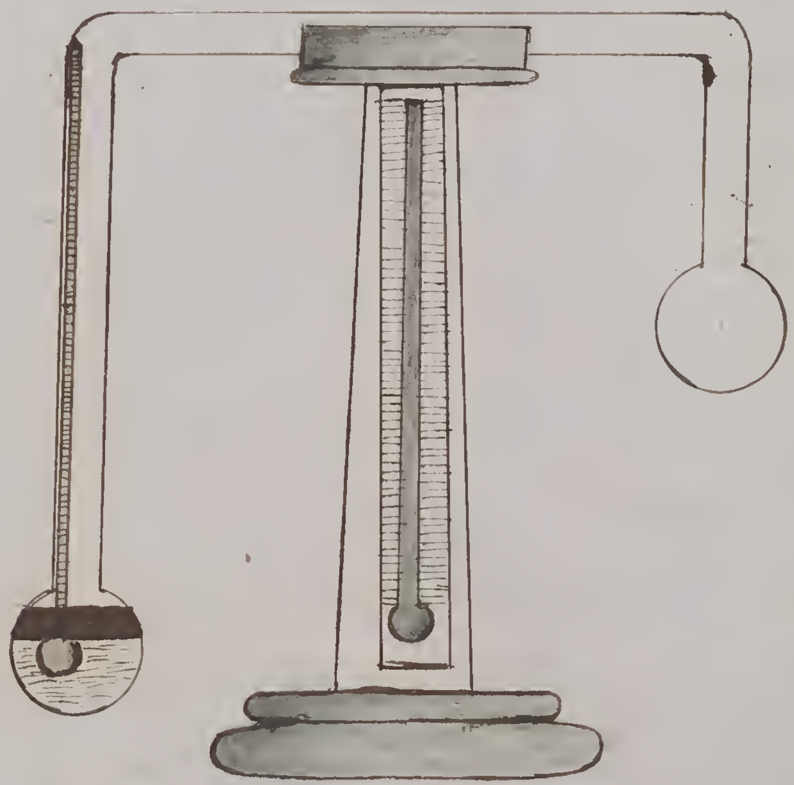
In general when a body is compressed, its capacity for heat diminishes, and a portion makes its appearance as sensible heat. Thus if we compress air suddenly heat is emitted. To illustrate this, we have a a this glass cylinder, in which a solid piston works. By forcing the piston down the cylinder forcibly, the air is very much compressed, so much so that a piece of tinder or phosphorous will be ignited. When a solid substance passes into the liquid form, a large quantity of heat is rendered latent. Thus water at 32° contains 140° more heat than ice at 32°. A pound of snow at 32° & a pound of water at 172° if mingled will a temperature of 32°. When a liquid passes into the form of vapour, it absorbs heat. Thus water absorbs nearly 1000° of heat in passing into steam. By Caloric of fluidity we mean that which is absorbed during

Wollaston's Cryophorus



fusion i.e; passing from the solid into the liquid state. Thus the caloric of fluidity of water is 140°. By Caloric of elasticity we mean that which is absorbed in passing into the state of vapour. Thus the caloric of elasticity of water is 1000°. These principles the process ~~for~~ producing cold artificially. One of the most common freezing mixtures is snow and common salt. A thermometer plunged in this mixture sinks to 0°. They are both solid bodies and have an attraction for each other; they will combine and form a liquid, Now in passing from the solid into the liquid state, heat is absorbed, which must be abstracted from surrounding bodies. A mixture of two parts of snow to one of salt will produce a cold of -5° The freezing qualities of this mixture can be easily shown. Wollaston's Cryophorus is the best adapted for this purpose; it consists of two bulbs united by a bent tube. One of the bulbs, the upper one, contains water, the other part is a perfect vacuum. The lower bulb is immersed in the freezing mixture. Water gives off vapour at all temperatures, and this vapour is condensed in the stem and lower bulb, thus vapour rises ~~conti~~ to supply its place. The vapour in passing from the water requires heat, which must be supplied by surrounding bodies; now in this case the heat is abstracted from the water, thus producing cold; and as more and more heat is abstrac-

Prof. Daniell's Pyrometer.



ted from the water, it finally passes into solid ice. Ether poured upon the hand produces cold; this is owing to the rapid evaporation, and the heat being taken from the hand it produces cold. The same result happens, if we pour it on the bulb of a thermometer; the best way of effecting this, is to envelop the bulb with muslin. Sometimes a cold of 30° can be produced in this way.

Lecture 30.th

The principle of the cryophorus has been applied to the construction of a Hygrometer, discovered by Professor Daniell. It consists of two bulbs connected by a bent tube, the whole is a vacuum, except the lower bulb which is half filled with ether. In the longer arm there a thermometer, whose bulb dips in the ether; there is a second thermometer in the stand, which indicates the actual temperature of the air. The upper bulb is covered with muslin. The lower bulb has a gilt ring passing round it to indicate more clearly the dew that is formed upon it. When an observation Ether is dropped upon the muslin around the upper one. The ether evaporating rapidly produces cold; and a distillation of the contained liquid takes place from one part of the instrument to the other, by which means the temperature of the ether is diminished; and dew is deposited on the outside. The Therm

ometer on the outside indicates the temperature at which the vapour of the air is condensed. The pulse-glass is another instrument designed to illustrate the same principle. It consists of two glass bulbs united by a straight stem, partly filled with spirits of wine, there not being a vacuum. If we apply the hand to it, and incline it slightly, allowing the liquid to fill the bulb and a part of the tube, evaporation takes place, and ebullition occurs; the rapid evaporation that takes place, causes a slight sensation of cold. The following is an arrangement for showing the ebullition of water. We have a retort filled with water, under which is a spirit-lamp. Previous to the ebullition small bubbles of air rise from the bottom until the meet the cold water, when they are condensed, making a crackling noise. These bubbles do not rise to the surface until the water is all equally heated, when ebullition takes place. Water cannot boil until it has an elasticity equal to that of the external air. The bubbles that rise are supposed to give forth steam, which soon fills the space not occupied by the water. When the retort is filled with steam, by placing a cork in the mouth, the ebullition ceases, this is caused by the pressure of the steam. But if water be poured on the retort, the steam is condensed, the water is relieved from the pressure, and ebullition again commences. Ebullition here takes place at a much lower tempe-

rature than in the first place. In every case as soon as the water is relieved from the superabundant pressure, ebullition takes place. If the retort be uncorked ~~after the~~ the mouth under water, after the steam has been condensed, the water will commence rising, and will do so, until it has nearly filled the retort. This owing to the fact that when the steam is condensed, a vacuum is formed, into which the water is forced by the pressure of the external air. These experiments illustrate 1st; that steam ~~may be condensed by the application of cold.~~ expels the air
2nd That steam may be condensed by the application of cold. If then we expel the air from a retort by steam, and by the application of steam condense the ~~air~~ steam, we will obtain a vacuum.

Evaporation occurs at all temperatures, It is a common impression, that vapour is sustained in the air like water in a sponge; persons constantly speak of "the air being saturated with moisture". That this opinion is fallacious may be proved by the fact that vapour is sustained in a vacuum as well as in air, and indeed forms in a vacuum more rapidly. This may be shown by a common barometer. Above the mercury is what is called the vacuum of Toricelli. Now if a small quantity of water be introduced, through the mercury into the vacuum, we will find that the mercury will descend half and inch, on account

of the expansion of the water into vapour, and its consequently increased ~~vapour~~ pressure. If this vapour be be heated, its tension will be increased, and the column of mercury be driven farther down. This experiment proves that the tension of vapour increases with the temperature. At every temperature vapour rises from water, that has enough elasticity to sustain a certain column of mercury. Vapour formed at a temperature of 32° supports a column of mercury of 2/10 of an inch; at 80° a column of one inch; at 180° a column of 15 inches; at 212° a column of 30 inches. There is an arrangement for showing a still higher temperature. It consists of a closed metallic vessel, half filled with water, and having a little mercury at the bottom. A tube open at both ends descends into the bottom of the vessel, and dipping into the mercury. Now if the water be made to boil, after it has passed 212°, it will cause the mercury to ascend the tube. The height of the column of mercury will show the excess of the pressure of the steam above that of the external air, since this tube is open at both ends, and the mercury must sustain the pressure of the atmosphere also. To indicate the height of the column, there is attached along the column a graduated tube. This apparatus is designed to exhibit the pressure of steam for different temperatures. A thermometer bulb is also inserted to

show the temperature of the steam. By this arrangement it has been found that the pressure of steam for one atmosphere is 212°; for one and a half atmospheres the boiling point is 232°; for two atmospheres 250°. If we allow the steam in this vessel to escape it will have a force sufficient to cause a wheel, with fans, to revolve. Indeed steam was first proposed to produce motion by direct impulse. Another principle ~~to~~ shown by this instrument, is the latent heat of Steam. Suppose we take a pint of water and evaporate it into steam, and then pass the vapour into ten pints of water, it will be heated to a tempera ture exceeding 100°, or the single pint 1000°. Vapour is perfectly transparent. If we introduce a small quantity of ether into a retort, filled with water being lighter than water it will float on the surface, and form vapour. If the heat of a lamp is applied, the vapour will expand until the water is driven out; but if the heat is withdrawn the vapour will be condensed and the water will return to its original position. This experiment establishes three important principles, 1st vapour occupies more ~~bulk~~ space than in the liquid form. 2nd vapour is perfectly transparent 3rd vapour is readily condensed by the application of cold.

# Lecture 32nd March 1st 49.

## Magnetism.

By a magnet we understand a body which has the power of attracting Iron in large a small quantities. By Magnetism we understand the unknown cause of this attraction. There is some power residing in the iron of attracting another piece of iron and for the sake of convenience we call it ~~attraction~~ magnetism. This attraction is evident at a sensible distance; if we hold a magnet about half an inch from some iron=filings, they will be put in motion.

A loadstone is a natural magnet. It is an oxide of iron, and is found in various parts of the world especially in beds of iron ore. In a mass (of the kind shown in the lecture) a considerable portion of the power is inert. The power is rendered more sensible, when cut into a regular shape. It is sometimes cut in a cubical form, and to the two opposite sides two pieces of soft iron are attached. Loadstones have been known to support more than 200 pounds.

An artificial magnet is a bar of iron or steel to which magnetic power has been communicated. If a magnet be rolled in iron filings, they chiefly collect about the two opposite points called poles. This power of attraction appears to reside principally near the extremities or poles. If a magnet be suppos=

ted as to be free to move in any direction, it will come to rest nearly in a north and south line. This may be illustrated by attaching a fine thread to the middle of a magnetized needle, and suspending it, the needle will come to rest in a north and south line. If the needle is drawn out of the position, it has when at rest, it will vibrate on either side of that position, until it settles in the same line as before; one pole always returning towards the north and the other towards the south. Hence we call one of them the North Pole and the other the South Pole. Iron attracts a magnet as much as a magnet attracts iron. This is shown by bringing a bar of iron near a magnetic needle. This attraction is therefore mutual. Iron is not attracted by iron.

The effect of the magnet is not destroyed by an interposed plate of any substance not magnetic. If a plate of glass be placed upon some iron filings, and a magnet be placed upon it, the magnet will lift precisely the same amount of iron filings through the glass, as if it was not interposed. A piece of tin foil or a piece of paper will act in the same manner. In general then the effect of any interposed body is not to weaken the magnetism, provided the plate is not magnetic. If we interpose an iron plate, the plate itself is lifted, because it is a magnetic body.

It is not necessary that the magnet be insulated; it loses nothing by being touched. In this respect it differs from electricity; because an electric body loses its electricity by coming in contact with another body.
The general proposition is that poles of the same kind repel each other, while poles of different names attract each other. Thus the North pole of one magnet will repel the North pole of another magnet, and attract the South pole. The South pole of one will repel the south pole of another but attract the North pole. Therefore a magnet is an instrument suited not only to discover the existence of magnetism in other bodies, but to estimate the kind of polarity affected by their different parts.
Upon bringing a piece of iron near a magnet, the former is rendered magnetic by induction, the intensity of the power thus conferred depends upon that of the magnet and upon the interval, which divides the two, becoming greater as the interval decreases; and greatest of all when in actual contact. We can determine the poles, by bringing the iron near a magnet. Each pole of a magnet induces the opposite polarity in the nearest end of an iron bar, and the same polarity in the remote end. This is shown by having a magnet suspended and bring a bar of iron in contact with it. If the bar of iron is sustained by the North Pole, the nearest end will have South polarity, and the remote end North Polarity. We can attach

other bars of iron and the same effect will be produced. They each become magnets in their turn, and each of their poles induces opposite polarity in the near end of the bar next to it, and the same polarity in the remote end. In this experiment the magnet sustains no loss of power, and consequently there is no transfer of magnetism from the magnet to the iron, but only the development of the same hidden principle. Then two magnetisms must therefore exist in all iron and steel. Indeed a magnet gains power by communicating it to other bodies. Thus if we apply a load to a magnet, which is suspended, as much as it will bear, on one day; the next day by increasing the load, we find that it will lift more; the day after it will lift more, thus becoming stronger daily almost indefinitely. We must, however, proceed very carefully in this experiment; because if the magnet be loaded so heavily that the load falls off, it loses more than it gains. Hence we see that magnets gain power by exercise.

All magnets should be provided with an armature, which is a piece of soft iron connecting the poles, and when this is taken off, it should be slid off sideways. Magnets in the form of a horse shoe are more convenient for many purposes than a bar magnet, the poles being nearer together. Soft iron readily acquires magnetism and as readily loses it. In the preceding example the magnetism acquired by the process of induction, is retained only so long as the magnet-

ic body acts upon it. Soon after the two bodies are separated, the bar loses all its magnetic power. Hardened steel acquires magnetism slowly, but it retains it permanently. When a bar of steel is placed very near a strong magnet, the action of the magnet commences immediately upon the the end of the bar nearest it; the North pole communicating South polarity to the nearest extremity of the bar. According to previous experience, we should expect to find the remote end of the bar a North Pole, but such is not the fact; a sensible time is required before north polarity is fully imparted to the remote end. Indeed if the bar be a long one, it sometimes happens that the North polarity never reaches the end but stops at some intermediate point. Thus the North Pole is succeeded by a second South Pole, that by another North Pole and thus several alterations occur between the two extreme poles before reaching the end of the bar. We can now understand why iron filings are attracted. Each is made a magnet in its turn. The magnetism in each piece of iron is decomposed, and has its N and S. Poles. In a long bar of iron, where we have a number of poles, we have comparatively weak magnetism.

Every magnet has two poles. Thus if we divide a bar in the middle, we shall obtain two perfect magnets, and although we may divide it a hundred times we shall still obtain two perfect magnets. It is im=

possible then to obtain a magnet having only one Pole. In this respect magnetism differs from Electricity, for an electrified bar when divided has its two parts exhibiting opposite polarity. Hence we infer that when we magnetize a body, there is not transfer of magnetism from one end to the other, but that each particle has its North and South Pole; and the magnetism consists in turning the North poles of all the particles in one direction, and the South poles in the opposite direction. Hence we see why iron filings are attracted, because when the magnet is applied to them, the magnetism in them is decomposed and their poles arranged in order. Iron filings arrange themselves about the poles of a magnetic bar in curves, called magnetic Curves. This is shown by placing a sheet of paper over a bar magnet laid on a board, and sprinkling iron filings on the paper, the filings will arrange themselves about the poles in curves; and this arrangement of the filings may be facilitated by slightly shaking the board, upon which the magnet is laid. They arrange themselves according to laws.

Lecture 33rd March 3rd '49.

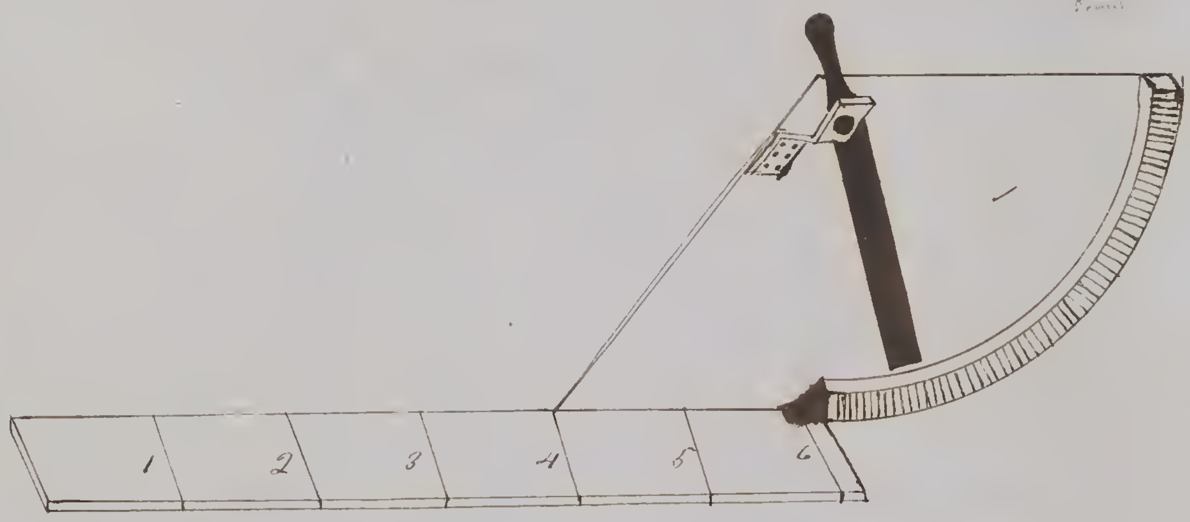
If a needle be balanced on its centre of gravity and then magnetised, one arm will preponderate. Hence we see why a needle has polarity. There is something in the Earth which draws it in a determinate direction, and this is situated not in the horizon but almost immediately below. In order to balance the needle, south end must be the heavier. A piece of soft iron when brought near a magnet becomes a magnet itself; its magnetism being decomposed by the action of the magnet. We have seen that the Earth itself is a magnet, and therefore ought to decompose the the magnetism of the iron, i.e; the iron bar ought to become a magnet under the influence of this terrestial magnet. This will be made evident, if we incline a bar of soft iron to the earth, in the direction of the pole of this terrestial magnet, we will find that the upper end is the north pole and the lower end the south pole, this is shown by applying the poles of the bar to the poles of a magnet. The magnetism was induced, in this case, by simply presenting the bar to the Earth in a position almost vertical. The most favorable position for inducing magnetism is that of a dipping needle, but it is not necessary to the delopement of some magnetism. When the bar is placed at right angles to the magnetic pole, there is no sensible perception of magnetism; but the more it is changed from that position, the greater becomes

the magnetism. We here see the power of induction of the earth. The attraction of the long bar for the magnet is greater than the attraction of the earth. The most favourable position for inducing magnetism is that when the bar is inclined to the earth's surface almost at right angles. The same effects may be shown by a much smaller bar; in which case it is required to use a more delicate needle. To show wether there is any magnetism in the bar, it should be presented to the needle at right angles to the magnetic meridian. By inverting the bar we reverse the polarity. This magnetism is rendered permanent by giving the bar a blow, when held in a vertical position. By doing this the magnetism is decomposed and the north pole remains the same, although the bar should be inverted or brought to a horizontal position. Rods of iron, which have for a long time been in a vertical position acquire permanent magnetism. Thus tongs, pokers, and the spires of churches are almost always magnetic. If we a piece of wire and twist it violently, when held in vertical position, it becomes permanently magnetic. The weight of a needle is not increased by magnetism. Hence we see that the attraction of the earth for one pole is equal to the repulsion of the other. The power of a magnet is impaired by heat; by a white heat it is impaired entirely. If we take a piece of soft iron, in the form of a Y, and attach the lower end to a magnet, each of the branches will have the same polarity.

But if we attach the branches to the North and South poles of a magnet, we will find the two magnetisms in the lower branch, one on one side, and the other on the other. Magnetism may be distributed in various ways. If we cut a piece of soft iron in the form of a star, we may render each point a North Pole, by applying the North Pole to the center. In the same way each point may be rendered a south pole by applying the south pole to the center. If we take a piece of iron in the form of a circle, and apply the North pole to the center, we shall have North polarity in the whole circuit. The circumference will have a south polarity if the ~~North~~ South pole is applied. The best form for a compass needle, is that, in which the directive power is the greatest, and the friction on the pivot least. The friction is very nearly in proportion to the weight of the needle. The form of needle recommended by Captain          is what he calls a pierced rhombus. A needle of that form is very light and has great directive power, and the friction is small.

Methods of Magnetism. The simplest method is called the method of single touch. It consists in rubbing one half of the bar on one pole, and the other half on the other pole. In this case the end which we rub on North pole becomes the south pole & vice versa. This method answers very well for small needles, but for large bars other methods must be used. The first

is that of Duhamel. Thus we take two bars, and unite their extremities by bars of soft iron; then take two magnets, applying their opposite poles, and place them on the center of one of the bars, drawing them towards the extremities; then reversing the poles, place them on the center of the other bar, and perform the same operation. The two bars must then be turned over and the operation repeated. The second method, which is much better, is that of Mitchell's. He takes several bars, which are to be magnetized, and arranges them in a continuous row. He then takes two bar magnets, places them parallel and near each other, separated by a thin piece of wood, not exceeding a quarter of an inch in thickness, placing the North pole near the South pole. He then commences at the middle of the bars and then to the end, and then turns back again. He then turns the bars over, and applies the magnets in the same manner. We might suppose that by applying two poles of a magnet to the bar no magnetism would be produced. But we must remember that there is no transfer of magnetism, but merely a development of a North and South pole in every particle of the bar. For this method the horse shoe magnet is preferable to the bar magnet because the two poles are nearer to each other. This is decidedly the best method known. The




Magnetometer.

power of magnets may be impaired in various ways by pulling off the armature, falling on the floor, striking or filing, or loading so heavily that the armature falls off. An instrument designed for measuring the strength of magnets is called a magnetometer. A small needle is supported on an axis, having an arc graduated and a scale of inches placed horizontally and graduated. This scale is designed to measure the distance, which the needle is repelled, and the distance is the measure of the repulsive force of the magnetic body.

Lecture 34th March 6th 1844.

Magnetism Continued.

In Terrestrial Magnetism there are three different elements to be considered, Variation, Dip, and Intensity. Variation the magnetic needle when freely suspended does not generally point exactly north. The deviation from that point is called the variation of the needle. A Magnetic Meridian may be defined as a vertical plane passing through the poles of the needle. The inclination of the magnetic to the astronomical meridian is what we mean by the variation. The variation then is determined by placing a compass on an astronomical meridian, and observing its bearing. To obtain the variation accurately much care must be taken. It is commonly assumed that the extremities of a needle are the poles, and the bearing is observed where the needle falls on the graduated circle. If however we have a needle of considerable width, as a bar magnet, it might be thought that a line drawn in the middle of the bar from one extremity ~~or~~ to the other would pass through the poles of the magnet, It is not, however, necessarily so; the axis may be inclined. Indeed it has been found by actual observation that magnetic needles frequently incline 1° or 2°. If then we attempt to determine the variation of such a needle, our observation will be in error by that entire quantity, viz; the inclination of the magnetic axis ~~the~~ the geometrical axis. This explains why compass needles differ; two

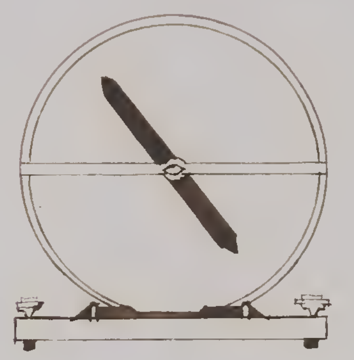
compasses may differ in their reading by several degrees. In order to determine the variation accurately, the needle must be ~~so~~ constructed that it can be inverted. The reading as indicated by the needle when inverted will differ from the reading when in the first position, by double the inclination of the magnetic axis to the geometrical axis. In ordinary surveying compasses this contrivance for inverting the needle is not used, but it is in nice variation compasses. This kind of observations has been made in almost all parts of the world. We represent these observations upon a map by a system of lines of equal variations. We first draw a line, connecting all those places, where the needle points exactly North. This line is called the line of no variation; and surrounds the globe. In this continent it is very regular, but very irregular on the Eastern continent. It crosses Lakes Huron and Erie, passes nearly through the centre of Virginia and meets the Atlantic near the middle of North Carolina. Every where upon that line the needle points exactly North. We then draw a line connecting all those places, where the needle points 5° West of North. This line passes almost exactly through Princeton, and is nearly parallel with the line of no variation. We then draw another line connecting all those places where the variation is 10° West. It passes very nearly through Portsmouth in N. H. We then in a similar manner draw lines of 15° and 20°

West variation. The line of 15° passes through the Eastern part of Maine. The line of 20° passes somewhat west of Halifax.
In the same manner we draw a line connecting all those places where the variation is 5° East. It passes a little to the West of Cincinnatti. The next line is that of 10°; it passes near the Western boundary of Missouri. The next is the line of 15°; of East variation, and so on upwards. This system of lines indicates the variation of the needle in every part of the United States. The variation at New York is 5° 34' West. The variation at Washington is 2° West. These lines are not stationary, they are all in motion. The rate may be set down as follows; in the Southern States it is 2' annually; in the Middle States 4'; and in the Eastern States 6' annually. From these results we may determine the variation for any time past. The variation East is now diminishing. The variation in the United States on the West are increasing and the East variation is decreasing. Besides this annual motion, the needle has a diurnal motion, depending upon the hour of the day. From 8 o'clock A. M. to 1 o'clock P. M. the North end of the needle moves westward, and returns again during the night. In the summer this motion amounts about to 15' and in the winter to 5'. This motion is exceedingly regular, and may be shown sufficiently nice. This change of variation is believed to depend upon the Sun, probably

although some have supposed that the sun exerts a direct magnetic influence. The mode of observing small changes in the variation is called the Method of Gauss. To a heavy bar magnet there is attached a small mirror at right angles to the magnetic axis. At a distance of two or three rods from the needle is placed a telescope pointing towards the needle; and if we look through the telescope, we will see it reflected in the mirror. Directly beneath beneath the Telescope is placed a graduated scale. By looking through the telescope we see the graduated scale, and as the needle oscillate a little from one side to the other, this graduated scale will seem to be in motion; and it is this motion we are to observe. The advantages of this system of observation is that it is unnecessary for the observer to come near the needle, as the observer nearly always has about him some substance which affects the needle. The Heat of the body will, also, create currents of air, which will affect needle. This is essentially the method that has been adopted in all modern magnetic observatories.

Dip of the Needle ——— An instrument for measuring the dip of needles is called the "Dipping Needle" It consists of a graduated circle placed in a vertical position and having a support for a needle at its center. These supports are planes of flat agate. There is commonly attached to it a horizontal circle; the whole resting upon

Dipping Needle



a tripod. The plane of this instrument must be brought into the magnetic Meridian, when the dip will be immediately indicated. At this place it deviates about 17° from the vertical position. By dip we always understand the angle which the needle makes with a horizontal plane. The dip at Princeton is 72°47'. If we go to the magnetic equator, which is not far from the terrestial equator, we will find that a magnetic needle, supported by its center of gravity, comes to rest horizontally. As we travel Northward the north end of the needle inclines downwards, increasing about 4° for each degree of latitude. This continues until we reach a certain point where the needle stands exactly vertically; it is called the North Magnetic Pole. If we travel Southward from the Equator the south pole of the needle begins to incline downward, and this dip increases until we reach a point where the south pole of the needle point vertically downwards. The North Magnetic Pole was reached in 1833. It was found in latitude 70° and longitude 97° by Captain Ross. The South Magnetic Pole has never been reached; but a dip of 88°40' has been observed, so that we know very nearly its position. It is believed to lie in latitude 76° and longitude 155° East. Observations of the dip have been made in almost every part of the world, like lines of variation.

Lecture 35th March 8th 1849

Intensity of the Earths Magnetism.

We measure the intensity of the earths magnetism, by the vibrations of a needle just as we measure the earths attraction by the vibrations of a pendulum. If we take a magnetic needle and deviate it, it will return to it former position by the force of the earths magnetic attraction. The number of oscillations made in a given time affords a measure of this attraction. "This intensity varies as the square of the number of vibrations made in a given time". For observations of this kind we generally employ a needle about 4 inches in length and $\frac{1}{10}$ or $\frac{1}{8}$ in diameter. In order then to determine the relative intensity of the earths magnetism in different parts of the globe, we transport the same needle and count the number of vibrations it makes in a given time. For this purpose we take a common time piece and as we cause the needle to deviate, we note the time. We then usually count off 10 vibrations and note the time, next 10 additional vibrations, next 10 more, always noting the time. We continue this series of observations up to 300 or 400 vibrations; these will occupy from 10 to 15 minutes, according to the strength of the magnetic needle. If these observations were made in the open air, currents of air, would interfere with the vibrations of the needle, it is therefore always covered with a glass case. An improved mode of observation has lately been adopted by Professor Bache of the Coast Survey. He suspends the needle in a perfectly tight case, from which the air

may be exhausted, so that the needle vibrates in a vacuum. The air is not entirely exhausted, but merely rarified to 1 or 2 inches. The advantage of this arrangement is that you avoid the resistance of the air, and the vibrations continue for a much longer time. Observations of this kind have been made in almost every part of the globe. The unit or standard of comparison is the intensity, observed by Humbolt in Peru about the year 1800. This was at that time supposed to be the least intensity anywhere existing on the globe. But feebler intensities have been observed as $\frac{8}{10}$ to $\frac{7}{10}$. In order to represent these observations on a map, we draw a line connecting all those places where the intensity is 1, the same as in Peru. Then draw another line connecting all those places where the intensity is 1.1 which is parallel to the other, and on this the undulations are greater. We then draw a line connecting all those places where it is 1.2. In like manner where the intensity is 1.3; 1.4; 1.5 &c. The least intensity which has been found is that of 7/10 in Africa. The undulations of these lines increase in higher latitudes. The line 1.7 is a closed curve and has two loops. In other words the intensity of the earth's magnetism is greatest a little above the United States. It has been proposed to call it a magnetic focus to distinguish it from a magnetic pole, by which we understand a place where the magnetic needle stands vertically. Within a few years

past, extensive surveys have been made in the British possessions to discover different degrees of intensity. The lo- of that focus has at last been determined. It is found in latitude 52° and longitude 97° a little north of Lake Superior. Around that focus is a portion of a curve of equal intensity and the curves gradually increase as they recede from the focus. From the form of the curves it is evident that there is ano-ther focus in Siberia, but it is more weakly than the American focus. We must, however, bear in mind that there are not two magnetic poles in the Northern Hemisphere, but two magnetic foci. Extensive surveys have been made by the British government in the Southern Hemisphere. Here the curves undulate somewhat as in the Northern Hemisphere, and hence it might be supposed that there were also two foci here. The largest curve is 1.5, the next 1.6, the next 1.7, these curves do not approach each other, or there is every reason to believe that there are not two foci in the Southern Hemisphere. Another thing is remarkable, the intensity in the Southern Hemisphere is 3 or 4 times greater than in the Northern. 1.8 in the Southern Hemisphere is 3 or 4 times greater than in the Northern. The result of observation is that the greatest intensity is about 3 times the least. It was formerly attempted to explain the phenomenon of terrestrial magnetism, by supposing that a great magnet was situated in the center of the Earth. If we ~~suppose~~ adopt such an hypothesis we must

suppose that the pole of this magnet is far below the surface of the earth, otherwise the intensity of this magnetic force would be many thousand times greater than near the poles than at the equator. If the pole of the terrestrial magnet is situated one mile beneath the surface of the earth, the magnetic equator must be 5000 miles distant from the poles. Now as the magnetic intensity varies inversely as the square of the distance, the intensity of the magnetic attraction at the poles, ought in that case to be as 1. to 25.000.000. But it is only three times greater at the poles than at the equator. Hence we must conclude that the poles of this magnet are far below the surface of the earth, so that you are very little nearer the magnetic pole at lake Superior than at the magnetic equator. We must suppose a magnet about 3000 miles long, having its poles about 2400 miles below the earth's surface. We must again suppose another magnet of less intensity, with its axis inclined to the first and having its pole under Siberia. Such a supposition will represent the phenomena somewhat rudely. But still it will not be sufficient to account for all the phenomena satisfactorily. The most satisfactory explanation of the phenomena of terrestrial magnetism is founded upon the action of electrical currents, of which we shall speak hereafter.

Fluctuations of the magnetic needle have been observed contemporaneously at very remote points of the earth's surface. Within

a few years past many observations have been made, and observatories have been established on every part of the globe, to observe at regular hours of the day once a month these fluctuations. In order to represent these fluctuations on paper we adopt the system of curves. We first draw vertical lines to represent the hours of the day. We then draw horizontal lines to represent minutes. Whenever the needle turns towards the North we draw the curve in that direction and the same when the needle turns to the south. The first curve represents an observation at the Hague in Holland running through 24 hours, the next represents an observation made at the same instant at Goettingen, the next at Hamburg, the next at Marburg, another at Leipsic and the last at Catania in Sicily. The whole distance from Hague to Catania is 1200 miles. The magnetic needle at all these places exhibited almost precisely the same oscillations. Similar coincidences have been observed repeatedly. In the year 1841, the most remarkable instance of this occurred. On this occasion, the movements of the magnetic needles were the ~~same~~ quite similar at Toronto in Canada, Greenwich, St. Helena, the Cape of Good Hope and at Trevandrum in India. There appears to be some influence that acts simultaneously over a great part of the earth. These singular movements have been called magnetic hurricanes by Baron Humboldt, and they are found invariably to accompany auroras. A brilliant Aurora will sometimes occasion an enormous deflexion in the needle. These facts evident show that the

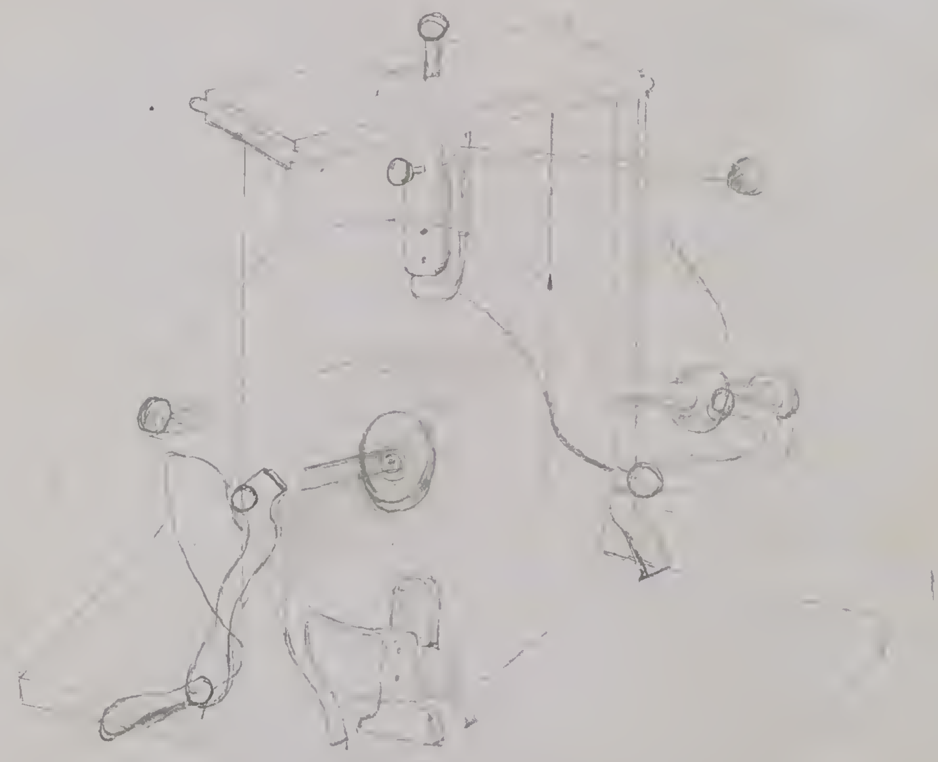
matter that forms the Aurora has magnetic properties, but they give no information respecting its origin. This is believed to be independant of the earth and the discussion therefore belongs to Astronomy.

Electricity.

Electricity is a term derived from the Greek word ηλεκτρον, which signifies amber. Amber when rubbed has the power of attracting light substances, such as pith balls, small pieces of paper &c. This fact was observed more than two thousand years ago by the ancient Greek Philosophers, hence the term electricity has been used to denote the unknown cause of electrical phenomena, and also the science which treats of these phenomena and their causes. For a long time this quality was not known to exist in any other substance than amber. The most general effect by which the presence of electricity is manifested is attraction. A glass tube rubbed with silk or flannel exhibits this electricity, and will attract light substances. If a pith ball is brought near the glass tube it is first attracted, then repelled. Resin rubbed with fur acquires the same properties. It is this property of amber, glass, and resin which is developed when they are excited we call electricity; indeed it is contained in all bodies more or less. Electricity is produced by the friction of all bodies. The friction of a metal will develop electricity; but metals require to be insulated before they develope it, because they conduct it away rapidly.

Electricity. Lecture 36th March 10th 1849.

An instrument designed to measure the intensity of electricity is called an Electrometer. It consists of two strips of gold leaf suspended from the metallic cover of a small glass cylinder. By this arrangement, the pieces of gold leaf are insulated, they are protected from the agitation of the air, and electricity is easily conveyed to them by bringing an electrified body in contact with the metallic cover. The approach of an electrified body causes the leaves to separate, or if previously separated to collapse, according to principles to be explained hereafter. A piece of dried paper, when rubbed exhibits sufficient electricity to support it on a wall. The electricity excited from glasses differs from that excited in resin. If we take a rod of glass and rub it with a piece of silk electricity is excited; now if we take a piece of resin and rub it, electricity is excited, but of a different kind; for the glass will attract and the resin repel and vice versa, hence they are in opposite states of electricity, which two kinds are called vitreous and resinous. And the general law of their action is that like electricities repel, and unlike attract each other. Thus if an insulated pith ball or a lock of cotton be electrified by touching it with an excited glass tube, it will immediately recede from the tube and from all other bodies which afford vitreous electricity, whereas it will be attracted by excited sealing wax, and all other bodies, which afford resinous electricity. In unelectrified bodies these two electricities exist in combination and neutralize

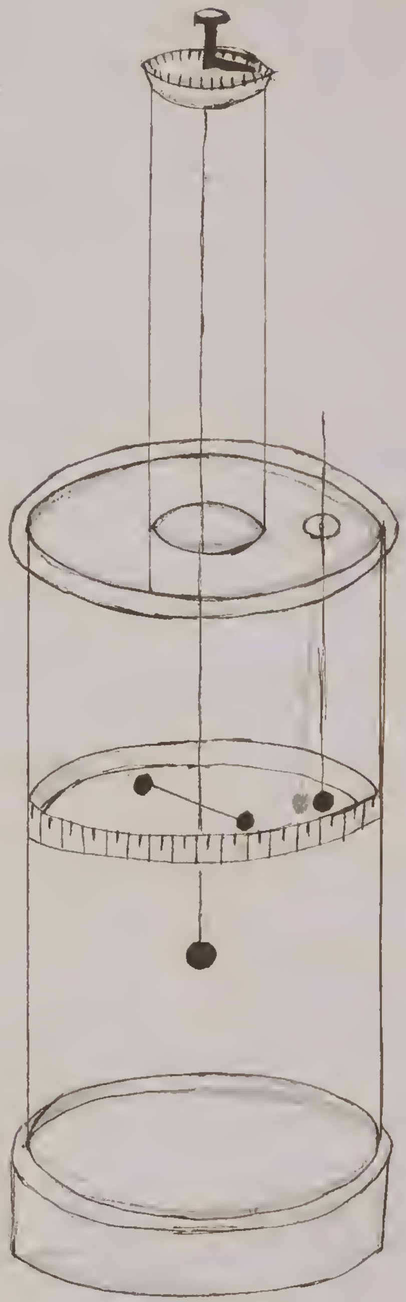


each other. It is only when separated that they exhibit their peculiar properties. For example, if we rub a glass tube with a silk or woollen cloth, the glass becomes positive and the cloth negative. The effect of ~~electricity~~ friction is to decompose the electricities. We may thus know when a certain body is electrified (i.e.) what kind of electricity it has by simply comparing it with glass and resin. As in the above example one kind of electricity is produced in the ~~glass~~ rubber and and the other in the body rubbed. In order to exhibit the phenomena more extensively we employ the **Electrical Machine**. An electrical Machine usually consists of a cylinder or plate of glass mounted so as to revolve against a cushion, which serves as a rubber. The electricity thus excited is received upon the prime conductor, which is a metallic cylinder, presenting considerable surface and supported by glass pillars. Upon the side of prime conductor nearest the glass cylinder are armed points, for rapidly conveying off the electricity. The intensity of the charge is denoted by a quadrant electrometer, which consists of a pith ball moving upon the arc of a circle; and the height to which the pith ball is repelled measures the intensity of the electricity. The intensity, however, is not in proportion to the size of the angle, because the ball rises much faster at first than it does afterwards. The rubber must not be insulated; it is generally connected with the earth. To show that the rubber and the body rubbed are of different electricities, suppose we bring a pith ball suspended by a silk thread near the glass and rubber, of an

electrical machine; we shall find that the ball is repelled by the glass and attracted by the rubber. If while we excite both electricities, we connect the rubber and prime conductor there ought to be no signs of electricity, and such will be found to be the case. We can by no method excite one kind of electricity without the other kind. Some substances are good conductors of electricity, among them may be mentioned 1st all the metals, they differ somewhat in their conducting power, but it is very little. Charcoal is an excellent conductor; and when made of hard wood, is one of the best. Water is a good conductor; thus when we apply a dry silk string to the prime conductor, it will conduct very slowly, but if we moisten it, it becomes a very good one. The human body is a good conductor; this is due to the moisture of the body, the different fluids it contains. Flame is a good conductor. Other substances conduct very poorly. Resin is a very bad conductor; so is glass, but it is apt to become coated with moisture, in which case it is rather a good conductor. Silk, wool and fur are very poor conductors. These last substances are commonly called non-conductors. The only difference between these two classes of substances, appears to be in the degree of their conducting power. Wood is an indifferent conductor; when green it is quite a good conductor, but when dry is a bad one. Dry air, also, is a poor conductor. A body is said to be insulated, when it is surrounded by non-conductors. A ball supported by a silk thread is insulated

because the thread of silk is a non-conductor. By the aid of the electrical machine we are able to show phenomena on a more extensive scale. If we have several bunches of cotton yarn connected with the prime conductor, when the machine is charged with electricity, repulsion will take place between the different threads. Another arrangement for exhibiting the same phenomenon, consists of three bells suspended from a metal rod, (which communicates with the prime conductor) with two small metallic balls between the bells. ~~The middle bell is insulated and then put in communication with the prime conductor. As soon as it is charged, the balls are attracted, and then being electrified are repelled, and attracted by the outer bells.~~ These balls are insulated. The bar which sustains the bells is put in communication with the prime conductor. The bell in the middle is insulated. The two outer bells are electrified, and attract the balls between them and then repel them, when they are electrified. The balls strike the middle bell by means of this repulsion, by which means also the electricity in them is conveyed to the middle bell, and from thence to the earth by means of a conductor. They are again attracted by the outer bells and again repelled, thus producing a continued ringing. This arrangement shows the attraction and repulsion of electricity. Another arrangement to show the same phenomenon is called the Electric Hail. It consists of a glass vessel, the bottom of which is coated with tin foil, and from

the top is suspended is suspended by a glass rod running up through the mouth of the vessel a metallic plate. Pieces of pith are placed on the bottom, and the metal rod is placed in communication with the prime conductor. As soon as the rod and plate are charged with electricity, the pieces of pith are attracted to the plate, and when they are electrified, they are repelled. If we have two wooden discs coated with tin foil; one of which is suspended and put in communication with the prime conductor, on being charged and small figures being placed between them, they will at first be attracted to the upper plate and then repelled. If we have two long narrow glass jars coated with tin foil one of which is insulated and connected with the prime conductor, the other with the earth, and then place a seesaw between them, consisting of metal rod with balls on the ends, when the machine is charged, a continued reciprocal motion is kept up, thus exhibiting the attraction and repulsion of electricity. Another arrangement called the electric sawmill. An insulated ball communicates with the prime conductor. Near this ball there is a wheel, consisting of several balls. Upon the ball being charged the other balls are attracted and then repelled, in this way a reciprocal motion is given. If we electrify a vessel of water, the particles of water will repel each other; and if we have capillary orifices through which water can escape by drops, when electrified it will flow in a stream. This appears to be owing to the repulsion of the particles.



Coulomb's Torsion Balance.

## Lecture 37th March 15th '49. Electricity.

An instrument called Coulomb's Torsion Balance, is used to measure the intensity of Electricity. The force used to estimate any given power of electricity is that of ~~etc~~ torsion, (i.e) the effort made by a twisted thread or wire to untwist itself. It consists of a small needle of lac, being a good non-conductor; this needle is suspended by a slender thread of platina, so that the least force applied to the extremity of the needle, will put it in motion. To guard the needle from the currents of air, it is placed in a glass cylinder, with a moveable lid, from the center of which rises another small glass cylinder, which guards the platina thread. Upon the last cylinder is a graduated ~~circle~~ circle, upon which moves a pointer or index, connected at its center with the platina thread, which is twisted when the index is turned. The lid of the lower cylinder is perforated with a hole, to allow access to the pith ball of the needle. On a level with the needle is a band surrounding the cylinder, divided into degrees and minutes. The mode of using the instrument is this; The index at the top of the upper cylinder is set at zero, and then the circle conveying the index with it, is turned until the needle rests opposite zero, on the graduated circle. In this situation the thread is free, [illegible] torsion. We now electrify the pith ball, and introduce it into the cylinder through the opening in the lid, until it is on a level with the needle. The ball of the needle being unelectrified is at first attracted to the pith ball and then repelled to a quarter or less distance, according to the degree of intensity of the electricity. The distance in the graduated arc to which the needle is repelled is a measure of the electricity. Coulomb determined by this

instrument the laws of electric repulsion. This he did by finding the relative forces of torsion required to bring those respective forces of repulsion to an equilibrium. We therefore turn the index upon the upper cylinder, in a direction opposite to that in which the needle moved, and observe the number of degrees, through which the index must be turned, in order to make the ball of the needle approach to any given distance of the electrified pith ball. Coulomb found that when the needle was brought to one half the distance, the forcible repulsion was four fold; and that for a third of the original distance, the repulsion was nine fold. i.e; the force of repulsion between two electrified bodies, at different distances, varies inversely as the square of the distance; or the force of electrical attraction and repulsion varies inversely as the square of the distance. By a process different from this last, Coulomb endeavored to prove the same thing. It consisted in bringing the suspended needle near to an insulated electrified sphere, and then deviate the needle, by which it is made to oscillate with greater or less celerity, according to it proximity, like a magnetic needle, and the number of oscillations in a given time, is the measure of the intensity. Electricity resides wholly on the surface of bodies. This can be shown in various ways. An arrangement for proving it, consists of an electrified sphere, suspended by a thread of some perfectly insulating substance. We also have two caps or hemispheres of tin foil or any other ~~substance~~ conductor so formed that when united, they accurately fit the surface of the spheroid. Now supposing the ball to be electrified, we then carefully apply the two caps, holding them by their insulated handles. When we remove the caps, we will find that there is no electricity whatever in the sphere, while the two caps will be found to contain the same quantity of electricity, that before was con-

tained in the sphere. Another arrangement for proving the same thing, is a glass globe coated with tin foil; and in the interior are suspended two metallic leaves. When the sphere is charged with electricity, there is no effect produced on the leaves, thus proving that the electricity resides on the surface. Another arrangement consists of a hollow sphere coated with tin foil; to the outer surface are attached small strips of metal. There is a hole in the top, through which we can introduce an electrified body. The sphere itself is insulated. When an electrified body is introduced, the strips of metal are repelled from the surface of the sphere. By this arrangement it can be shown that the least possible charge passes to the surface. We then come to the conclusion, that a hollow sphere will contain as much electricity as a solid sphere, and the metal may be extremely thin without impairing its conducting power. Electricity is not distributed uniformly over the surface, except the body is a perfect sphere, but it is unequally accumulated in different parts of the surface, according to the figure of the body. In conductors of an elongated shape, the electricity is accumulated in the extremities, and taken more or less from the central parts. Upon a globe the electricity has the same tension over every part of the globe, and it is found that upon a spheroidal conductor the tension of the electricity ~~depends~~ at the extremities ~~depend~~ and at the middle of the conductor is in the ratio of two axes. The following is an arrangement to show that the tension electricity depends on the extent of surface. We have a sheet of tin foil wrapped several times around an insulated cylinder. Upon unwinding the metallic sheet and increasing the extent of electrified surface, an electrometer connected with the cylinder will indicate a decline in the intensity of the charge at every successive enlargement of the surface. If we electrify a conductor terminating in a point, the tension

at the point will be very great, indeed the tension according to theory would then be infinite, if we could have a mathematical point. Electricity ~~is~~ conveyed off almost instantly and silently by a point. If we hold a fine needle near the prime conductor, the whole charge is rapidly conveyed off. This is a most important principle especially for lightning conductors. From every point of an electrified body electricity rapidly escapes. To show this, we have a small wheel, having metallic points at right angles to the radii. When we put it in communication with the prime conductor, it will revolve. The wheel is insulated, so that the electricity can escape only by the points, and it is this rapid escape of electricity from the points, that produces the rotary motion in the wheel. Another arrangement illustrating the same thing, consists of an inclined plane and railway. We have two wires running parallel, forming the inclined plane, and connected at their extremities with a metallic bar, which is in communication with the prime conductor. Upon these wires at their lower ends rests the two extremities of the axis of a wheel, whose radii are armed with points turning backwards. When the rod is electrified, the electricity will pass along the wires and electrify the wheel, and as the electricity is discharged from these points, the wheel is put in motion, and runs up the inclined plane upon the wires. Here is another arrangement to illustrate the same principle. We attach an upright rod to the prime conductor, and place upon it a glass flask. If we electrify the glass, the inside is electrified, ~~+~~ and the outside slightly by induction. Now if we hold

on obliquely to the flask, rotation will take place, caused by the passage of the electricity into the [illegible].

Induction. When an unelectrified body is brought near an electrified conductor, its electricity is decomposed. Suppose we have an electrified globe and near it an insulated metallic cylinder, but not near enough for a spark to pass. Two pith balls are suspended at each end of the cylinder and one in the middle. We shall observe that the balls at the two ends immediately diverge, but the one in the middle remains at rest. That this is not due to any transfer of electricity may be shown by simply taking away the globe, when the balls will fall to their first position. To determine the kind of electricity induced in the cylinder, we must present an electrometer or insulated pith ball, to the globe & to both ends of the cylinder, and we shall find that the electric globe when it decomposes the natural electricity of the conductor, attracts the opposite electricity to the nearer end and repels the same kind to the remote end.

These two kinds of electricity may be separated. Place two cylinders of the same size end to end near the globe. The middle point will then be at one end of each cylinder, and taking them apart, the opposite electricities may be exhibited in their farther ends. From these experiments we conclude that Induction precedes Attraction. This may be shown thus; we have two metallic discs, one resting on a glass stand, the other suspended from one arm of a balance also insulated. By a fine wire suspend two pith balls near the upper disc, and connected with it by a flexible wire. Now let the lower disc be charged; the pith balls will begin to move, and the upper disc to move towards the lower one (i.e.) electricity was communicated to the balls through the upper disc before the lower disc was attracted to the lower disc

Electricity continued. Lecture 38 March 15th 1849.

The Leyden Jar so called from the place of its discovery, which took place in 1746. A Philosopher of Leyden wishing to charge some water with electricity, held a glass vessel containing some water in in his hand; a rod communicated with the water and prime conductor. After electrify=ing the water, he wished to discharge it from the machine, and for this purpose he took hold of the rod with his other hand, and immediately received a shock. The principle of this phenomenon was soon after discovered. It was discovered that the water served as a conductor on the ~~outside~~ inside and the hand on the outside, hence the following arrangement was substituted. A metallic vessel was substituted for the water and another vessel for the hand and between these two was placed the glass vessel, which in the first place contained the water, but now holds the inside metallic vessel. The effect in this arrangement was the same. The construction of an ordinary Leyden jar is this; the jar is of glass, and is coated nearly to the top inside and outside with tin-foil, the remaining portion being covered with varnish or a thin layer of sealing wax. To the mouth is fitted a cover of hard dry wood; through the center of which passed a metallic rod, terminating above in knob, and below in a small chain that rests on the bottom of the jar. The jar is usually charged by presenting the knob to the prime conductor, a series of sparks passes between the jar and prime conductor. It is discharged by means of the discharging rod, which is a bent wire armed at each end with glass knobs and insulated by a glass handle. To discharge the jar we apply one end of

the knobs to the outside of the jar, and the other one to the the knob of the jar, when a flash of intense brightness and a loud report follows. It can also be discharged by making the connection by means of the hands

The Leyden jar acts by induction. An unelectrified body (the outer surface) is brought very near to an electrified body (the inner surface) supposing the interior to be in communication with the prime conductor, without the possibility of communicating with each other. The electricity of the outer surface is then decomposed and as that on the inner surface is vitreous, this kind must be repelled and there remains on the outside the resinous electricity. The opposite sides of the jar are in different states, therefore, and this may be shown by presenting the insulated pith ball alternately to one and the other, the knob of the jar of course indicating the electricity of the inside. This will first attract and then repel the pith ball, after which the outer coating will attract and then repel it. The outside of the jar must not be insulated, for if it be we get no charge. If we attach a silk chord to the jar and suspend it from the prime conductor no charge will be received. An insulated jar may however be charged positively by connecting its knob with the rubber, the rubber being insulated, and the prime conductor uninsulated, or by connecting the outer coating with the prime conductor, and the knob with the earth by conductors.

When the jar has been charged in the ordinary, if we approach the discharging rod again we shall get a second spark,

it is obtained from what is called the residuary charge. We [suppose] it to be due to all the electricity not being conducted off at the first discharge, the attraction of those particles which are nearest each other being very great. With a very large battery the residuary charge may give a very severe shock. The theory of the Leyden jar may be best understood by a coated pane of glass, which is insulated and upon each side is placed a piece of tin-foil to within about an inch of the edges. To the upper edges two threads are attached directly opposite one another. If we bring it in communication with the prime conductor, & ~~apply~~ it may be charged in the same manner as the Leyden jar. We charge it, by bringing the inner coating to the prime conductor and apply the knuckle to the outer coating, thus connecting it with the earth. When it is charged the two pith balls which are attached to the strings will each be repelled by the coating nearest it, and both strings will form equal angles with the surface of the glass. If now we touch one of the coatings with the finger, the ball on that side immediately falls, while the other ball doubles its angle of elevation. If this be repeated successively it will be observed that the angles intercepted between the two threads is a constant quantity. Now this repulsion is due to the excess of free electricity on each side of the pane. By the law of induction the particles of electricity on the nearer surfaces of the coatings exert a greater attraction for each other than repulsion for the particles of the same kind, inasmuch as the latter are a greater distance from the former.

A second jar may be charged, by communication with the first. The conditions are that the first jar ~~may be made~~ must be insulated and the knob of the second jar must be communicate with the outside of the first. Three or four jars or more may be charged in the same manner, except that all the jars must be insulated except the last, the knob of each communicating with the outer coating of the one before it. There is however always a little waste of electricity from imperfect insulation. In all these experiments the jar is said to be charged positively or vitreously. We may charge a jar resinously by presenting the outer coating to the prime conductor, holding the jar by the knob.

If we take two jars and charge them thus in opposite ways we can show alternate attraction and repulsion. For this purpose we suspend an insulated pith ball between the two, it will first be attracted to one of the jars and then repelled, when it is attracted by the other and then repelled. The pith ball may be made in the form of a spider, causing a pleasing illusion at a distance.

When two jars are charged with opposite electricities, the one positive by the other negatively on connecting the knobs of both no discharge takes place. The reason is obvious. By the law of induction the attraction of the kinds of electricity for each other is greater at the short distance between the inside and the outside of the jar, than at the distance between the two knobs. If the jars are insulated this attraction is considerably diminished by the other attraction of the two kinds of electricity on the

outsides of the jars and in this case a discharge will take place.

The electricity is accumulated on the surface of the glass and the coatings serve merely as conductors of the charge. The object of the coatings is to put all the particles of glass in communication with each other. This is proved by the fact that when the coatings are moveable, so that they can be removed when the jar is charged; neither of them exhibits the least sign of electricity and the charge may may be taken off the glass jar by connecting the two sides of the successively with the finger or some other conducting substance. Any non-conductor will answer the same purpose as a glass. A plate of Mica, for instance, coated with tin foil. A ~~st~~ stratum of air may be made to answer the same purpose. This is done by having two discs coated with tin foil, the upper one being connected with the prime conductor. When ~~the~~ a discharge of the jar is passed through the human frame, a shock is felt which if slight is felt at the wrists, but if more severe in the chest and muscles of the body.

# Electricity Lecture 39th Continued.

Electricical Instruments: The Electrophorus is an instrument for accumulating small quantities of electricity. It consists of a flat smooth cake of resin in a wooden dish. When this is rubbed it is rendered negatively electrical. Electricity may be obtained from it but the amount is very small that is obtained from it directly. If we place a metallic plate having an insulated handle upon this resin, and touch it with a finger, and lift it by the insulated handle we will get a spark. This electricity is obtained by induction. If we simply lay it on the resin and lift it again we get no spark, if however we touch it and it and then lift it off we will get one. The electricity is not transferred from the resin to the conductor it is simply induced. This can be explained by bringing the disc near the prime conductor; the electricity of the plate is decomposed. If now we remove it from the prime conductor we will not get any spark when touched; but if we touch it while in communication with the prime conductor, and then remove it we get a spark when touched. In order that the disc be permanently charged there must be an opportunity for the vitreous electricity to escape. The same thing is true of the electrophorus.

Another arrangement for containing electricity is called the sulphur cone. We melt a small quantity of sulphur and pour it in a wine glass. As it cools insert a glass tube so that the mass may be raised by it when hard. Then coat the wine glass with tin foil and attach a small wire for a conductor. When the sul=

phur is cooled, place an electrometer near the wire glass, and attach the wire to the electrometer. Raise the sulphur cone & immediately the leaves will diverge. The cause of the electricity is most probably the melting and cooling of the sulphur, since it disappears after a short time. This therefore is a reservoir for electricity.

There are several instruments known by the name of condensors, the object being to render feeble electricities sensible. One arrangement is Volta's Condenser. It consists of a metallic disc supported by a glass handle, and adapted to the plate of the gold leaf electrometer. The plate of the electrometer is connected with any body supposed to contain electricity, but not sensible, as with the discharged prime conductor. The disc is placed over the cap of the electrometer, but not in metallic communication with it, being separated from it by very small wax balls. Now if there is any electricity in the lower disc, though insensible to the gold leaves, it will act on the upper disc by induction. Touch the upper disc with the finger, which will allow the opposite electricity to escape, & the gold leaves will immediately diverge indicating the presence of electricity. The electricity is said to be condensed, so that when we break the communication of the two discs, the electricity is sensible. This experiment shows that very slight friction of metal excites electricity and that it is one of the best and most delicate modes for detecting it.

Cavallo's Multiplier, serves also as a condenser and is said to multiply electricity. It consists of four square brass plates. Three supported by glass rods and one by a brass one. One is movable and

slides back and forth, but is prevented from coming nearer than ½ an inch. There is also a bent wire, which upon being pressed back touches the plate. If we wish to obtain electricity of considerable tension, we must combine several jars forming what is called a battery. Their knobs being all connected by a rod, and all being made to rest upon a strip of tin foil; so that both the outer and inner coatings are in communication.

Lane's Discharging Electrometer is an instrument the object of which is to graduate the discharge at pleasure. It consists of a common Leyden jar, to the rod of the jar is attached a bent glass ~~tube~~ rod rising vertically to the same height with the knob of the jar, and terminating also in a knob of brass, through which slides a horizontal brass rod having knobs at its extremities. This horizontal rod can thus be moved any required distance from the knob of the jar. If then the jar be charged and a communication be made between the outside of the jar and the end of the horizontal rod, the two electricities will be brought near one another, and when they have acquired sufficient tension to pass the distance between the knob of the jar and the knob of the horizontal bar nearest it, a combination then takes place producing a spark. The distance then of the inner knob of ~~of the~~ horizontal rod from the knob of the jar will regulate the intensity of the shock, rendering it thus a convenient apparatus for communicating electrical shocks.

The Unit jar (invented by Harris) is an arrangement for measuring the amount of electricity in any charge. It consists of a small insulated Leyden jar having a wire communicating with the in-

side and another one with the outside, & both terminating in knobs. The knob on the wire communicating with the outside is movable, so that the two knobs can be placed any distance apart, as in Lane's Electrometer. When the jar is charged a spark will pass between the two knobs. The arrangement is placed between the Electrical Machine and a large jar, which we wish to charge, so as to announce by its repeated discharges (which may be counted) the number of discharges, which have passed into the jar. The amount of electricity required to charge the small jar is regarded as the unit, and this unit can be increased by sliding the knobs farther apart from one another.

Cuthbertson's Balance Electrometer is an instrument for measuring for the charge of electricity. It consists of an insulated support, through which a rod runs terminated at each by knobs, (A & B) and capable of being balanced. On this rod is a slider by means of which the arm upon which it is may be made to ascend or descend. From this support another rod extends, and is terminated in a ball. (C) This ball is connected with the prime conductor and another ball (D) with a Leiden jar. When therefore C is highly charged it will repel the ball A to D. from which it is conveyed to the jar and an explosion takes place. The extent of the charge is measured by the slider, the unit of which is in grains. (Fr.)

In a dark room. Lecture 40th Electrical light.

Electrical light is manifest when the fluid passes through a bad conductor. Accordingly when the fluid passes through a good conductor no light is seen, even in the darkest room. When however there is a break in the current, as when the fluid passes through air or some bad conductor, light is developed. This light it has been conjectured was due to condensed air. An instrument for proving this is Kinnersly's Air Thermometer. It consists of a glass tube closed at both ends, made air tight by brass caps, through each of which passes a moveable rod terminated within by small brass knobs. Through the lower cap is inserted a small glass tube open at both ends, and turned upward in a direction parallel with the cylinder. A small quantity of water is introduced into the tube, sufficient to cover the bottom of the cylinder and rise a little way up the tube. The two balls being set at some distance from each other, and a spark from the Leyden jar passed between the air in the cylinder is rarified and the water ascends in the tube, but descends again when the explosion ceases. This sudden rarifacation of a portion of the air before the electric spark, must cause a sudden and powerful compression in the portions of the air adjacent and this appears to be a sufficient cause for the production of electrical light that accompanies the discharge of the jar. The electric spark has many peculiarities worthy of more particular notice. The first thing is its zig-zag form. This is well explained by the same theory, viz; the electric fluid in its passage through air condenses the particles of air before it, & thus meets with

a resistance which turns it off laterally, in which direction it goes some distance when the air is again condensed and its course is again changed, and so on it proceeds until it reaches the conductor towards which it is aiming.
The second thing to be observed is that in addition to the zig zag motion, branches of light appear on either side of the spark towards the resinous or negative electricity. Thirdly, the portions of the spark nearest to the knobs are the brightest. Near the knobs the color is white, in the centre it is purplish. Those persons who contend for the doctrine of two fluids explain this by saying that the feebly illuminated part is the point where the two fluids unite.
When electricity is discharged through water a spark is often visible. This is probably due to the condensation of air in the water, unless the water itself be sufficiently condensed to be the cause of it.
The properties of the electric spark may be exhibited by a variety of experiments. When the electrical machine is put in rapid motion brilliant circles of light appear upon the glass plate of the machine. Metallic conductors, if they are perfectly continuous transmit electricity without any peculiar appearances, but if a slight separation occurs, a spark will be visible at every separation. Innumerable devices may be exhibited by pasting narrow strips of tinfoil on glass and cutting it into different shapes, so that wherever there is an interruption in the circuit, a spark passes and that point is illuminated. If an interrupted conductor of this kind be passed around a glass tube in a spiral direction, and one end of the tube be presented to the prime

conductor a brilliant line of light will run the whole length of the tube. Words, flowers or any figures are produced by a proper disposition of interrupted lines of metal on a glass plate. The light of the electric spark continues for no appreciable time. This can be proved by the following arrangement. It consists of a circular disc connected with a wheel so as to revolve rapidly. On the face of the disc three crosses are drawn. Now if this be made to revolve very rapidly (say thirty revolutions in a second) the crosses will not be distinguishable but a circle of black will be seen of a confused outline. The cause of this is that it requires an appreciable time for the impression of a cross to be made upon the retina of the eye, and before this impression is made (such is the velocity of the disc) the impression of another cross requires to be made, and thus the impression of each is confused or nothing distinct is seen. But revolve the disc in a dark room, and illuminate the face successively by sparks from the prime conductor, and then the three crosses will be seen distinctly, though the disc revolved 50 times a second. They would be seen if the disc revolved a hundred, a thousand times per second or in any appreciable time. Hence we infer that electrical light travels with unappreciable velocity, for if it were the least appreciable crosses on the disc could not be seen. The electric spark passes with increased velocity through rarified air. The spark from the prime conductor in the open air will pass but 5 or 6 inches while in an exhausted tube it will pass 4 feet or more. If a pointed wire be introduced into the top of an exhausted receiver, the wire outside terminating

in a knob, and the knob be connected with the prime conductor, as we exhaust the vessel, ~~until~~ it becomes lighter and lighter until it is entirely exhausted, when a beautiful light will pervade the whole vessel.

The appearance of the spark is modified by the nature of the substances through which it passes. These experiments are made by making the given body a part of the circuit of communication, between the inside and outside of of the Leyden jar. A ball of ivory exhibits a beautiful crimson; an egg a similar color; a lump of sugar gives a white light, which remains some time after the spark passes; Fluor-Spar exhibits an emerald green light or sometimes a purple, which continues to glow some seconds. A piece of chalk is affected in the same manner. If the thumb be placed over the space which separates the wires connecting the two sides of the jar respectively the illumination is so powerful that the blood vessels may be distinctly seen.

Lecture 41st Electricity continued.

Influence of points. When a point is brought near a prime conductor the electricity is conveyed off rapidly and silently. When this experiment is performed in a dark room, the point is tipped with light at a very great distance. The subject of points is one of great importance in its application ~~to~~. If we present a ball to the prime conductor we get a series of sparks; but if we present a point ~~to the~~ ball at twice the distance no spark will pass. Hence we perceive then that the effect of the point is to draw off the charge quickly and silently, and at a much greater distance than the ball. The electric fluid is received by the ball with an explosion. The influence of a point may be impaired in various ways. A point discharges the fluid without an explosion. To be effectual it must be entirely unobstructed. If we introduce a point into a glass tube, and present it to the prime conductor, the electricity will pass by sparks, and the sparks will go exactly to the point. The peculiar effect of a point is almost entirely destroyed by enclosing it in a glass tube. It may also be impaired by placing a number of points near it. Also between two plates of glass inclined at an angle. The electricity will pass by sparks. The several points interfere with each other and the fluid passes by a spark, as it acts more like a ball than a point. Hence several points draw off less electricity than a single one. If we attach a pith ball to a point, the fluid will pass by a spark. Also by interposing a sheet of paper, a piece of flannel or a piece of silk or by placing a point opposite a point. Hence we conclude that a point is most effectual when

isolated. Nothing can be brought near it without impairing its power in some degree. This subject will be treated more fully in another connection.

Mechanical effects of Electricity. If we have two pieces of glass between which a strip of gold leaf is placed, and place them between two boards which may be screwed together so as to keep the glass in place. If this be placed between the wires of the universal discharger, and a charge be passed through the gold leaf, it will on examination be found to be partially dissipated and oxidized, and particles of gold leaf are always driven into the glass. Metals then in the form of thin foil are oxidized. The effect of interrupting the circuit may be shown by pasting a strip of tin foil on a piece of board, the tin foil having several interruptions. Now if we place wafers on these interruptions, and also where there are no interruptions, and pass a charge through it, the wafers on the interruptions will be thrown off while the rest remain. This experiment shows therefore when there is a good conductor, the electric fluid will pass freely and without much repulsive force, but where an interruption occurs a repulsive force is exhibited.

Various combustibles may be fired by electricity. If we place a small quantity of ether in a plate upon the prime conductor, and pass a a spark through it, it will inflame. The charge is immediately conveyed off by the flame, and almost as rapidly as from a point. A piece of phosphorus is readily fired by the charge from a small jar, & this is most conveniently done by passing the charge by means of a bent wire. Alcohol can be inflamed also by means of the charge of a jar, the

alcohol however must be heated somewhat beforehand. Common resin is one of the most readily inflamed substances by electricity. If we sprinkle some powdered resin upon a block of cotton & pass a small charge through it, it immediately becomes inflamed. We might suppose the gunpowder would be fired the easiest of all these substances; but such is not the case. The charge appears to scatter the powder without producing any other effect. It can however be fired, and the best means for doing it is, to paste a strip of tin foil on a small piece of board, and make a few interruptions about the 1/8 of an inch in breadth, then interpose in part of the circuit a wet string. Place powder upon these interruptions & pass the charge & it will then explode. The mere interruptions might prevent the powder from scattering & also inflame it, but the wet string renders the experiment more certain. This wet string establishes the analogy between the common electrical machine & the Galvanic Battery. Gun Cotton is also readily fired by means of a spark. Explosive gases may be easily fired by electricity, & in this case it is necessary to have interruptions in the circuit. For this purpose a small glass tube is inserted in a metallic vessel, and through this a brass wire passes extending nearly to the opposite side of the vessel. The end of this rod is held to the prime conductor, & the electricity affecting the whole of it, passes from the opposite end to the side of the vessel in a spark and thus fires the gases in the vessel. If we interpose a plate of glass between two metallic points and pass a charge through it, the glass will generally be perforated. This experiment will succeed better with a glass tube one end of

which is closed, since the fluid finds more difficulty in passing around a tube than a glass plate. If we take a glass tube closed at one end and place it between two points, by introducing one within it and the other without, & pass a charge through it, the closed end will be perforated. This experiment succeeds better & usually by introducing a simple drop of oil into the tube.

Magnetism may be communicated by means of an electric charge. If we pass a charge of a jar through a needle not magnetised we may impart some magnetism to it, by means of a simple instrument called a <u>helix</u>. It may be called a screw and consists of a spiral wire, & for these purposes it is wound round with thread in order somewhat to insulate it. Now if we introduce a needle into it and pass a charge, it will be rendered magnetic. There are two kinds of helices, the right handed & the left handed. A right handed helix is one in which the axis is placed vertically and the turns proceed in the direction of the sun's daily motion. A left handed helix is one in which the turns proceed in a contrary direction. We wish now to determine whether a needle undergoing this operation has polarity or not, & in what position the poles are. Now if we have the point of the needle towards the resinous side of the jar, we will find upon applying it to the North Pole of the magnet, that there is repulsion; this therefore is a North Pole. Thus we see with a right handed helix the north pole of the ~~magnet~~ needle is towards the resinous side of the jar. Now if we introduce it into the same helix in a reversed condition, we will find that the eye of the needle

is turned towards the resinous side. Hence the poles have been reversed. In the left handed helix we will find that the South pole is turned towards the resinous side of the jar. If we obtain steam of high tension, say 2 or 3 atmospheres, it is always electrical. Electricity is given out when the steam is condensed and the boiler under the same circum=stances is also electrical.

# Lecture 42nd

Electricity of Steam. In the last lecture it was remarked that steam of high tension, showed the presence of electricity. If we place a steam boiler on an insulating stool and make a communication with the steam as it issues with the electrometer, the gold leaves will be repelled, thus indicating the presence of electricity. It however requires 2 or 3 atmospheres to show this. In large boilers where as much as 2 or 3 atmospheres can be obtained the effect on the gold leaves is very apparent. This electricity appears to be liberated at the instant of condensation. Before the steam escapes from the boiler it is not electrical. The electricity escapes or is liberated when the steam is condensed.

There are several experiments designed to detect the direction of a current in electric discharge. For this purpose we interpose a card painted with vermillion vertically between two points. Upon passing the charge from one point to ~~another~~ the other the charge is perforated. There are some peculiarities about this perforation which indicate the direction of the current. The reason we employ a card painted with vermillion is to indicate the direction of this current. The perforation in the experiment was near the vitreous point. Now the peculiarity is that although the distance between the points (one of which is on one side of the card and the other on the other side) is considerable still the perforation is not made directly opposite the upper point, but opposite the lower one, ~~where the perforation takes place~~. i.e. the electricity passes through the air until

it comes opposite the lower point when a perforation takes place. This has been thought by some to the supposition of a single fluid, that is to say there is an excess of electricity in the inside of the jar, which as soon as the jar is discharged passes to the outside, since the excess, if there be any on the outside passes off by the hand. Now the upper point is in communication with the inside of the jar; hence as soon as the jar is discharged, say the supporters of this hypothesis, the free electricity ~~the~~ passes off to the outside to supply this deficiency. But the lower metallic point, corresponds with the outside, so that the free electricity passes through the air until it comes opposite the lower point, that is the outside, when a perforation is made in the card and the deficiency in the lower point is supplied, while no perforation whatever is made opposite the upper point. We think however, that this is owing to the fact that the resinous electricity meets with more resistance from the air than the vitreous electricity does. Another circumstance connected with this experiment, and unfavourable to the hypothesis of but one fluid, is the formation of burrs on the side next the lower point. These are due to the repulsion of the electricity. At the instant of the discharge, the particles of paper along the path become powerfully electrified and repel each other. We do not think this circumstance favours either hypothesis. When this experiment is tried in rarified air the appearances are a little varied. There are now three perforations

exactly equidistant between the two points. There are near the vitreous knob. What happens in this case happens pretty generally, that is when the experiment is tried in a vacuum, the perforations are midway between the two points. Commonly there are several of these perforations. The difference between the two experiments is due to the resistance of the air, & this experiment is regarded as favoring the hypothesis of two fluids; but we must remember that resinous electricity experiences more resistance from the air than the vitreous therefore in common air the perforation is opposite the lower point. We may vary the experiment in regard to steam in the following manner. If upon the gold leaf electrometer we place a vessel of water and drop hot metallic balls the gold leaf strips are repelled thus developing electricity. This electricity may be regarded as the electricity of the boiler & not of the steam. This electricity is believed to be due to evaporation. The water in this vessel should contain a little salt, for if we use pure water, we shall obtain very little electricity. The evaporation of salt water may then be set down as an important source of electricity. The electricity of the atmosphere comes from the evaporation of the vast body salt water of which the ocean is composed.

Lecture 43rd Electricity Continued

When a building is struck by lightning, there is usually seen a flash of light, which consists of sparks similar to those drawn from an electric machine. There instances however on record of buildings being struck by lightning and persons killed, when no flash was perceived. This is believed to be due to what has been called the returning shock. Suppose there is a large cloud electrified several miles in extent. This must be considered as an insulated conductor, and is usually vitreously or positively electrified. Suppose its electricity is vitreous as is usually the case, then that will decompose the natural electricity of the earth, repelling the electricity of the same kind into the earth and attracting electricity of the ~~same~~ opposite kind. Now if the surface of the earth be uneven, the electricity will chiefly accumulate in ~~points~~ points, so we will have a cloud charged with positive electricity and the tops of the hills under it charged with negative electricity. These two electricities attract each other and when the intensity is sufficient to pass through the intervening distance, there will be a discharge. The discharge will generally be towards the highest object, so that if there are two hill of unequal height, the higher hill will receive the discharge, and the attraction for the resinous electricity in the lower hill being removed, it will return to its former state in the earth. This then is called the return shock. The same principle may be shown by having a metallic globe having strips of tin foil upon it in the neighborhood of the electric machine. If the prime conductor be electrified its influence upon the globe will be evident from the repulsion of the

tin foil. If however the charge be conveyed from the conductor by means of the hand, no effect will appear upon the globe, Here the conductor represents the cloud, the hand the highest hill, the globe the lowest. The conductor decomposes the electricity of the globe, and repelling the same kind causes the tin foil to recede, but upon conveying off the charge by the hand, the electricity of the globe returns to its former state. There are several contrivances to exhibit electrical figures which are analogous to that of magnetism. One is to place a metallic star or any other figure upon a plate of resin, and bring the arrangement near the prime conductor. The particles under the star will be electrified, while the others will not, and they will be capable of attracting light substances. So if we sprinkle an orange colored powder upon it, composed of sulpher and red-lead, the sulphur will be retained be the electrified particles, and the unelectrified particles will attract the lead.

The human body often gives indications of electrical sparks. Individuals have been known, who upon touching the cap of the electrometer cause the leaves to diverge. Some persons can produce an effect upon the electrometer, when they stand upon an insulated stool. By using the condenser we can obtain electricity from almost every individual. This appears to be electricity generated in the system somewhat analogous to the electrical fish. There are certain fishes capable of exhibiting electricity, from some of which a spark may be obtained and a feeble charge given to a Leyden jar. We sometimes hear of instances in which the electricity of the human body is developed in a remarkable degree. There was a case in N. Hampshire in the year 1837 of a lady who gave electrical sparks of an inch and

a half in length & at the rate of four per minute. This state of electrical excitement lasted for a month after which it gradually declined.

Lightning Rods. The attraction which a thunder cloud undergoes may be shown by suspending a lock of cotton, designed to represent a cloud, and putting it in communication with the inside of the jar, which communicates with the prime conductor. If it be electrified, it will be attracted by any neighbouring object, & will show this attraction at a considerable distance; for example a small house, since the cotton is charged with positive electricity from the inside of the jar, and the building with negative by induction. The cloud will therefore be attracted. The outside of the jar is connected with the outside of the house, thus forming when the cotton is attracted a continuous circuit. Now if the circuit be broken and an explosive mixture inserted where the break occurs, the building will be blown to pieces. If a point be made part of the circuit then the charge will pass off quietly but if a ball be inserted it will pass off with a noise.

Principles for the construction of lightning rods. In the first place, the rod should be of sufficient size, for if it is too small part of the charge pass off into the building. For an iron rod 3/4 of an inch in diameter is not considered too great; for a copper rod 1/3 of an inch in diameter may answer.

Secondly. The rod should be continuous from top to bottom. It is difficult to have a continuous rod, hence it is common to have links. These are very bad for wherever there is a link there is a break in the circuit. The two pieces of iron may not touch or if they seem to touch, there may be rust between them, which is a bad conductor. There are two way by which links may

be avoided. The first is by the use of a wire rope, wound round the whole rod except the top, which must be made of a solid piece of iron. The second method is by having the different portions of the rod screwed together. The third is, the rod should always terminate in a point at the top. It is common in this country to make the rod terminate in three points. The French use but one. It is generally that one point is as good as three & much better than a collection of points. Fourth; the rod ought to terminate at the bottom in wet earth, or better still in a large collection of water, dry ~~water~~ earth being a very poor conductor of electricity. It is not sufficient that the earth be moist at certain seasons of the year, the rod must terminat where it is constantly moist. For it is during a dry spell that the most danger is to be apprehended from lightning, when the earth is dry for some distance below the surface of the earth. This moisture is seldome found at a less depth than 6 feet, & sometimes it is necessary to 10 feet. In the fifth place; a rod will protect a circle whose radius is twice the height of the rod above the building. Thus if the rod be 10 feet above the building it will protect a circle of 20 feet all round.

# Lecture 44th Galvanism

In the year 1767 a German author mentions the following experiment. If a plate of zinc and copper be placed in the mouth, with the tongue interposed between them, on bringing the edges together a peculiar metallic taste is observed. If one be pressed between the upper lips and gum and the other be placed under the tongue, on bringing the edges together a flash of light is seen which may be seen whether in the day or night. & whether the eyes are open or shut. These effects are due to Galvanism. In 1790 Galvani observed the contraction of the muscles of a frog, when a communication was made between the nerves and muscles by a compound rod of zinc & copper. If a strip of zinc and copper be united at one end by a joint & the end of one of the rods be connected with the crural nerve, & the other with the muscles of the toes, a muscular contraction will take place. Galvani supposed that the muscular system of animals contained positive and the nervous system negative electricity, therefore upon joining the two there ought to be a discharge as in the case of the Leyden jar. Volta however supposed that electricity was excited by the contact of the two metals zinc & copper. By pressing two plates of zinc and copper together, feeble electricity is excited, which may be shown by using the electrometer & condenser; & this electricity is said to be due to the simple contact of the two metals. This theory of Volta led to the invention of the Voltaic pile. He said that if the contact of two plates one of copper & the other of zinc developed feeble electricity then by repetition of the pairs, we would increase its intensity. This was constituted upon this theory, it however contained an additional element, viz a piece

of cloth moistened with a solution of salt or acidulated water. The voltaic pile consists of a series of copper & zinc plates separated by pieces of cloth dipped in salt water. First we have a copper plate then a zinc plate, then a piece of cloth, another of copper another of zinc another of cloth and so on alternately. If we make a communication with the upper plate and the electrometer, we will not perceive any signs of electricity, but by bringing the upper plate in contact with the plate of the multiplier, and placing it on the cap of the electrometer, we may render it sensible. If we make the communication with the first copper plate and the first zinc plat with the fingers when moistened we will get a faint shock; the fingers must be moistened since we cannot perceive the slightest effect through the dry skin. With sixty pairs the effect is quite sensible. Another apparatus invented about the same time and constructed upon the same theory of contact is the Dry Column of De Luc. This consists of an immense number of little circles of common writing paper having silver leaf on one side & a preparation of zinc on the other. These are placed in a glass tube one on top of the other, with the silver sides all turned in one direction, so that the silver comes in contact with the zinc. The metals used in this instrument must be some not easily oxidized. A column of this kind exhibits electrical repulsion, and will continue in operation several years. This repulsion may be shown by making each end of the column communicate with an electrometer. The silver end has positive and the zinc end has negative electricity. Now if the finger be placed on the cap of one electrometer, the electricity is conveyed off and the leaves fall, while the leaves of the electrometer at the other end of the column often move.

Now to prove that the silver end has positive & the zinc end negative electricity we will reverse the column. Now if in this position one end be applied to the electrometer & it causes the leaves to collapse, if we apply the other end they will diverge. The electricity in this pile therefore is due to the contact of the two metals.

The voltaic pile was replaced by the trough Battery. It consists of square plates of copper & zinc about 4 or 5 inches apart, and is sometimes called Cruikshanks battery. These plates are soldered together in pairs and are placed in a trough, forming partitions which are to be filled with dilute acid. These plates are so arranged that the same metal shall always be on the same side. This form is now entirely abandoned from its liability to leak. The form now generally used differs from the trough battery in having large plates of zinc a foot square and plates of copper of twice the size, foalded so as to surround the zinc but prevent from coming in contact by little piece of cork. Thus there are double the number of copper plates that there are zinc. A strip of copper is soldered to each of the copper plates, & another strip to each of the zinc plates, so that all the zinc plates are connected as well as the copper. The ends of these strips constitute the poles, & by joining these we will get & feeble sparks. The advantage of this battery over the last consists in the zinc being exposed to the two sides of the copper & also in being able to remove the battery from the acid whenever it is wished. It is very active when fresh, but very soon declines. the zinc becoming corroded.

Another form is Daniell's Battery, which consists of a cylinder of copper with a solid rod of zinc immersed in it. The two are

separated by a vessel of porous ware, that is unglazed porcelain, so that the zinc & copper communicate only through this vessel. We then on the outside of this porous vessel a solution of sulphate of ~~zinc~~ copper & within it we have dilute sulphuric acid. Instead of the vessel of porous ware, we may use any animal membrane. The advantage of this battery is, that it is permanent in its action. Another form a little different from the last is the sulphate of copper Battery. It consists of a vessel of copper some 8 inches in diameter, with a small cylinder of copper within it. Between these two copper cylinders is introduced a zinc cylinder of intermediate size and the space between them is filled with a solution of sulphate of copper. Upon connecting the poles we get feeble electricity, no spark will be visible, but it will affect a galvanometer. A Galvanometer is an instrument consisting of a magnetic needle poised upon a point & surrounded with one or more coils of copper wire covered with silk for the purpose of insulation. The ends of the copper wire are left free or terminate in small cups of mercury, for convenience of communication with the source of electricity. When this needle is placed parallel to the coil & in the magnetic meridian, it immediately deviates when the electric current passes through the coil, & the deviation is either to the East or West according to the direction of the current. By reversing the position of the wires the needle will be driven in the opposite direction. The most powerful Battery now known is Grove's. It consists of a cylinder of zinc immersed in a tumbler of dilute acid & a strip of platina, which is introduced into a vessel of porous ware & filled nitric acid. One cup is called an element & the battery consists of a combination of these elements, having the platina of one cup connected with the zinc of the preceding one

## Lecture 45th Galvanism Continued.

In Groves Battery, mentioned in the last lecture we use platinum instead of copper as in the other batteries, & we also use zinc amalgamated, i.e, coated with mercury. The zinc is immersed in water containing about 1/12 part of sulphuric acid, while the platinum is immersed in pure nitric acid. When we connect the two poles we get a feeble spark, but by connection with the Galvanometer the effect is very striking. By making the communication of the two poles of the battery through points of charcoal we get a brilliant light. Then wire uniting the two poles become ignited while the battery itself is quite portable & to a great extent constant in its action. The fluid will not pass any distance through air. The heat generated is not due to the ordinary kind of combustion, since the presence of oxygen is not necessary. The experiment will succeed equally as well in a vacuum or in nitrogen, hydrogen or oxygen gases, or a spark may even be obtained under water, by bringing the wires connecting the poles near together under water. If we draw one end of one of one of the wires connecting the poles over a steel bar there are scintillations resulting from the combustion of the steel. In experimenting with a Galvanic battery, some beautiful phenomena are observed. It is necessary that the experiments be conducted in a dark room, in order to observe the effect of the battery. If a piece of charcoal prepared from box wood be attached to the end of one of the wires of the battery, and brought in contact with the other, then there will be a constant transfer of small particles of charcoal from one pole to the other, from the positive side to the negative side, and

this transfer is always in the same direction. If we change the position of the charcoal points, the transfer will still be from the positive to the negative pole, & this transfer is accompanied with a beautiful flame. If the points be removed from each other about half an inch an arch of light will surround them, due probably to the rise of heated air. This flame may readily be blown off. If a piece of steel wire be placed between the ends of the wires coming respectively from each pole of the battery, it will burn as in oxygen gas. Should the ends of these wires be tipped with charcoal and a strip of zinc be placed between them, the zinc will burn with a bluish flame accompanied with a cloud of vapor, called philosophers wool. Any of the metals may be melted by bringing them in communication with the poles of the battery. If one pole of the battery communicates with a vessel containing mercury and a steel rod communicating with the other pole be placed in the vessel, there will be then combustion of both the mercury and steel. The mercury fumes arise from the vessel and the light which rises is not due to the combustion of the ordinary kind. The presence of air is not necessary to the success of the experiment, as it may be carried on equally as well in a vacuum, or there may be a passage of the current under water. If the poles of the battery be united by a platinum wire, it will become red hot, ~~it~~ and if the wire is short it will melt. Platinum wire is heated most readily of any metal and iron next, then brass. If the wire from one of the poles be placed in a vessel of mercury, and a file be

made part of the circuit, then by drawing the wire from the other pole over the file, the file will burn. A strip of tin foil introduced into the circuit will also burn and it burns with a light vapor. Copper leaf and sheet brass will burn in the same manner. Gold and silver leaf burn with a delicate green tint. Powder may readily fired by the battery, and that too at any distance from it by means of the wires from the two poles. It is only necessary to make platinum ~~wire~~ pass through the powder, which forms part of the circuit. The platinum wire heats heats & fires the powder. If pass the current through potash, it is melted and decomposed, so that we get a combustion of potassium burning with a flame violet. Ether may be fired fired receiving a spark on the surface. A brass wire and knitting needle are readily burned by making them form part of the circuit.

The electricity obtained by means of battery will give a shock as readily as that obtained from an electric machine, the only difference is that in the case of the battery it is only given when the circuit is made and broken. The intensity of the electricity from the battery depends upon the number of elements employed, so that to get a severe shock it will require a number of alterations of elements. Thirty six elements of Grove's battery will give a shock sufficient for ordinary purposes.

## Lecture 46th Galvanis continued

Theory of the Galvanic Battery. If we take a strip of amalgamated zinc & a small strip of copper and immerse them in dilute acid, we will observe no peculiar action as long as the metals are not in contact. If we however connect them by strip of copper, we will immediately observe bubbles of gas appearing on the surface of the copper, They do not appear on the surface of the zinc. These bubbles are hydrogen gas. The zinc however wastes away as is proved by its loss of weight from day to day and the liquor is found to contain oxide of zinc. We hence infer that the water has been decomposed, that hydrogen is evolved upon the surface of the zinc, and the oxygen unites with the zinc forming oxide of zinc. If the communication had been made between the two plates by means of glass rod, or any nonconductor of electricity, no gas would have been evolved. We hence infer that the power excited is electricity. If we connect one of the wires of the galvanometer with each of the immersed plates, the needle is immediately deflected. If the plates were sufficient large we would observe a minute spark when the contact is made. If the communication was made by means of a slender wire, it would immediately become red hot. This experiment shows that there is a continuous flow of electricity. The vitreous electricity flows in the fluid from the zinc to the copper and through the air when the plates are not immersed from the copper to the zinc. This then we call a voltaic circle & there can be no considerable excitement of electricity without this circle. The The object of the sulphuric acid is to dissolve off the oxide of zinc, which is continually formed, If we take a perfectly clean plate of zinc and immerse it in pure water, we will get

the same electricity as when we immerse it in acid, but it only lasts for a few minutes. The zinc immediately becomes covered with oxide of zinc, and stops the flow of electricity. It is the decomposition of the water then which is believed to afford the electricity. A compound battery consists of a series of such pairs as have been described. The intensity of the electricity ought to be in proportion to the number of alterations, supposing there was no waste of power. There is however a waste which generally occurs. In Grove's battery we use platinum immersed in nitric acid, instead of copper immersed in dilute acid. Here no hydrogen is evolved upon the platinum, still water is decomposed. The oxygen of the water decomposed unites with the zinc as in the common battery, but the hydrogen unites with the oxygen of the nitric acid thus forming nitrous water.

Galvanic Electricity differs from the electricity of the common machine in three particulars. First, its low intensity. This is regarded as measured by the distance a spark will pass in air. Second, in its great quantity. The quantity is regarded as measured be the immense quantity of water it will decompose. Faraday has estimated that the quantity of electricity employed in decomposing a single drop of water is equal to that of a powerful flash of lightning. Third, the difference is that of a continuous current. The following is an arrangement invented for the purpose of decomposing water. It consists of a vessel filled with water, & having two glass tubes parallel with each other, inserted vertically. These tubes are inserted over strips of platinum, the right hand strip communicating with the negative pole, and the left hand strip with the positive pole of the battery. When a current is thus passed the water will be decomposed, the oxygen of the decomposed water going to the left hand tube

or positive pole; the hydrogen to the right hand ~~pole~~ tube or negative pole. The bubbles in this experiment are evolved in connection with the platinum strips, that is in connection with the poles. Between the strips there are no bubbles, & this has been regarded as rather mysterious. It may be explained as follows, by assuming that all the particles between the strips undergo decomposition simultaneously, the oxygen going off in one direction and the hydrogen in another. Thus for example each particle of oxygen may be made to go to the left, uniting successively with each particle of hydrogen until it reaches the opposite pole or opposite strip of platinum, where meeting with no particle hydrogen it is decomposed and enters the tube. In the same manner every particle of hydrogen may be drawn off to the right. Thus this process going on constantly a succession of particles of oxygen & hydrogen are disengaged towards both strips of platinum only while none are in the middle. One important application of electro-chemical decomposition, is known by the name of the electro-type. The object of this is to copy medals engraved plates &c. A medal to be copied is placed in a solution of sulphate of copper & connected with the negative pole of a voltaic-battery. A small plate of copper communicating with the positive pole of the same battery is placed in the solution. In this arrangement the passage of the electric current decomposes the sulphate of copper, & causes the copper to be deposited on the medal. In case the medal to be copied should be a non-conducting substance, it is only necessary to cover it with a thin coating of some metal, which will render it conductive. To prevent the deposition of copper in the edges and upon the reverse of the medal, these parts should be covered with a varnish not to be acted on by the solution.

# Lecture 47th Electro Magnetism

Electro magnetism is the magnetic effect of electricity. In the year 1819 Professor Oersted of Copenhagen observed that a magnetic needle was deflected by an electric current passing over it. Thus let BD& represent the course of the current, passing over the magnetic needle, & CF9 the course of the current under the needle. Now if the end of one of the wires from the battery be placed in the cup A and the other in the cup B, these cups containing mercury for convenience of communication, then the needle will be deflected towards the west. If we reverse the position of the wires, then the North pole of the needle will be turned towards the east. It was found then that a galvanic current has the power of deflecting a magnetic needle, and that too always in the same direction. M. Ampere has given a convenient rule by which we always may determine the direction in which the needle will ~~may~~ be deviated; the rule is this, consider yourself lying in the direction of the current, the positive electricity entering your head & passing out at your feet, with the face turned towards the magnet; then the North pole will always be deviated towards the right, this is the principle of the galvanometer. The galvanometer has already been described. The sensibility of this instrument depends upon the number of coils of wire. The delicacy of the galvanometer may be increased by another contrivance, which is this; suppose we have two needles ~~xxxx~~ attached to the same support with poles turned in opposite directions, one of the needles being within the coil, the other without. The influence of the current is to turn the system in the same direction. The outer needle serves the purpose of an index, but that is not its entire object. Action & reaction are always equal and in opposite directions. If then the electric current

impels the pole of the needle in one direction, the magnet ought to impel the current in the opposite direction, & if the conducting wire be free to move, we ought to be able to render this motion sensible. The following is an arrangement for showing this. It is called Marsh's vibrating wire & consists of a wire designed to form part of the ~~xxxxx~~ circuit, with its lower end immersed in a vessel of mercury & its upper end suspended from a loop. The wire is therefore free to move in both directions. Now a horse shoe magnet is placed near it so that the wire is suspended between the two poles. Now a communication is made between the poles of the battery, by putting the wire in the cup of mercury, & the other in connection with the rod to which the wire is suspended. We might suppose the North & south pole would neutralize each other & no motion would ~~xxxxx~~ ensue, but they conspire & throw the suspended wire in the same direction. When a current is passed through the arrangement, the North Pole will be deflected ~~xxx~~ towards the right or since the magnet is stationary & the wire moveable, the wire itself is turned towards the left. If the south pole were on the same side, the wire would be deflected toward the right, that is the south pole of the magnet would be deflected towards the left. As it is however the South pole is opposite to the North, & the wire is deflected towards the left. Thus the North & South poles conspire to throw the wire in the same direction. If we reverse the current, the wire is thrown in the opposite direction. This then is the reaction of the magnet on the wire.

An arrangement similar to this has been made to exhibit rotation. A wire is suspended from a loop with its lower end dipping in a vessel containing mercury. In this vessel of mercury a small magnet is placed vertically & the wire is suspended directly over this. If now the wire from one

of the poles of the battery, be placed in the cup of mercury & the other in communication with the suspending rod, so that a circuit is formed, the wire thus suspended will revolve around the magnet. This is due to the action & reaction of the magnet & the electric currents are equal & in opposite directions, so that the wire must be deflected to the left in every position, thus describing a circular orbit. This power is said to be a tangential force, since it appears to act in a direction of a tangent to a circle around the pole of the magnet. A current of electricity passing through the battery, has precisely the same qualities as in the conducting as in the conducting wire, so that if a battery could be supported so as to be free to move, it would revolve under the influence of magnetism. An arrangement of this kind was designed by Ampere. It consists of a copper vessel of a form of the periphery of a circle; the centre of the circle being out, and a zinc vessel of the ~~the~~ same form fitting loosely in the copper one, so as to allow the interposition of some dilute acid. These vessels are suspended from the top of a rod, the copper vessel being stationary, while the zinc one is moveable on a pivot. Whenever a current is passed through by the action of this self-constituted battery, the zinc vessel will rapidly revolve. A variation of this experiment was proposed by Mr. Marsh. He suggested that the copper vessel be so supported that it might also revolve. In doing this both vessels revolved, but since the current ascends in the copper and descends in the zinc, the two vessels properly revolved in opposite directions. If we have a wire coiled round in a series of circles, with the lower end immersed in a vessel of Mercury, and the upper suspended by a loop then upon passing a current through the spiral by communication with a battery, & bringing a magnet near it, the wire ought to be deviated in the opposite direction. A spiral of this kind ought

to take up a position at right angles to the magnetic meridian under the influence of the earth's magnetism. This is an important principle. Two spirals are affected in the same manner; as also a single conducting wire.

Finis of lecture 47th

## Lecture 48th Electro Magnetism.

The electro dynamic cylinder is formed of copper wire a simply a helix, with no magnetic power until a current is passed through it. This was invented by Ampere. De la Rive's Ring consists of a coil of wire, one end of which is attached to a piece of copper, and the other to a piece of zinc. The whole is fastened to a piece of cork, designed to float in dilute acid. Here the copper and zinc form the battery, and the apparatus is acted upon by a magnet, being attracted by one pole and repelled by the other. We have before shown that a wire conveying an electric current always throws the north pole of the magnetic needle to the right. Now this force not only deflects a magnetic needle, but it will develop magnetism in a bar not magnetic. So that new magnetism is developed in soft iron. So that it is only necessary to connect the two poles of the battery and bring the bar to be magnetised under it, and it will become a magnet. A magnet thus formed will not be very strong. If we coil the wire connecting the poles of the battery upon itself, it will increase the effect in proportion to the number of coils. If then we take a helix, which consists of a large number of coils of wire, with the current flowing in the same direction, and introduce a needle into it, it will become magnetic. In a right handed helix i.e; one in which when we look down vertically upon it the coils proceed in the direction of the sun's daily motion, the point of the needle towards the negative pole of the battery will be the north pole; the other will be the south pole. If we introduce the needle into the helix in the opposite direction the poles will be reversed. Soft iron is thus magnetised instantly

but it looses its magnetism very soon. Steel requires some time to become magnetic, but it retains it permanently. For the left handed helix, the north pole of the needle will be turned towards the positive end of the battery. If we have the helices combined, and introduce a needle into it, we will get a magnet with two south poles. We have a south pole at each end and a north pole in the middle. If we reverse the position of this combined helix, we will get a North pole a each end and a south pole in the middle. By a serial combinations of helices we can get a needle with any quantity of poles. An electro magnet is a large helix with a bar of soft iron running through. The north pole of the magnet is always thrown to the right, if then the North pole of a bar inserted within the coil, be without the centre of the coil, it will be drawn inward by that force. In this way a large may be supported contrary to the force of gravity. Another arrangement involving the same principle, is a piece of soft iron bent in the form of a horse shoe, with two coils, which fit the arms. The horse shoe is balanced directly above the coils, and when current is passed through them the shoe is drawn into them, and held there as long as the current passes. This reciprocal motion may be produced at a considerable distance. A magic ring consists of two semicircular rings of soft iron, with handles. These fit to one another accurately, forming a circle. If we introduce a little coil fitting loosely, and pass a current through them, the two will be held together with a force sufficient to support upwards of fifty pounds, or even 100 lbs. These irons are only ½ an inch in diameter. As soon as the current ceases to flow they fall apart. This magnetism is then developed instantly by this little helix. For the same

reason a piece of soft iron bent in the form of a horse shoe and wound round with wire may be made to hold an armature with considerable force, by passing a current through it. A larger one of the same formation is instantly rendered magnetic by passing the current; as soon, however, as the current ceases to flow, it looses its magnetism. In all these magnets we have but one wire, which is continuous, and wound round in the same direction. The large one belonging to the College and made Prof. Henry, consists of a piece of soft iron in the form of a horse shoe, and weighing 100 lbs. It is wound round with several hundred feet of copper wire in 30 separat pieces; each piece being wound round a small portion of the magnet (about one inch). All the similar ends are soldered to one wire and all the opposite ends to another wire, so that the current flows through all 30 pieces at the same time. This magnet will support several 1000 lbs, and when made was the most powerful one ever constructed. The battery used in connection with this instrument consists of a single element. Upon looking at it we might suppose that there were twenty two plates of zinc and as many of copper, but the zinc plates are all connected, as are also the copper plates, so that they act as one plate. Each plate is very nearly a foot square, so that the whole surface covers some twenty feet; and it is found that more magnetism is developed in this way than if the same surface was occupied by a large number of ~~plates~~ separate plates. Steel bars may be magnetised by rubbing them upon an electro magnet. This is the best method of making permanent steel magnets.

although magnetism may be developed by introducing the bar into a helix.

The influence of two conducting wires. We have seen the influence of a conducting wire upon a magnet, and of a magnet on a wire. We now wish to see the influence of one wire upon another. For this purpose we use two batteries. We must bring the wire from one of the batteries in connection with a wire suspended from a rod, and dipping in mercury, so as to form a descending current; now if the wire from the other battery be brought beside this, so as to form a descending current in it also, the two wires will be attracted to each other. If however one of the wires be reversed, and consequently the current, the wires will repel each other. Hence we infer that currents moving in the same direction attract each other; while those moving in opposite directions repel each other.

## Lecture 49th

The following is an arrangement to produce rotary motion. It consists of two coils of wire, one of which is fixed, the ~~th~~ other revolves about an axis. By connection with the poles of battery, a current may be made through each of these coils. The current passes by a wire through a slender silver spring, which presses against the axis of the inner coil. This axis consists of two portions slightly separated from each other and of a semicircular shape. Now all that is necessary to make the inner coil revolve is, to reverse the current twice in every revolution, and this effected by this axis. The outer coil has a current constantly passing in one direction and for example let the inner ones be at right angles to it. When this is the case each of the silver springs presses against separate portions of the axis. It should however be mentioned, that this inner coil consists of two pieces of wire wound in opposite directions, one running in the same direction with the outer coil, and the other in the opposite direction. If then the two stand as above, and a current pass through the semicircle, connecting with the wire running in the same direction as the outer coil by means of this spring, the two will be attracted. When however they are in the same line, a break occurs in the axis, and the current is reversed; caused to pass through the wire running in opposite direction to the outer coil, and therefore causing repulsion. Thus the passing alternately through the wires of this movable coil, which run in opposite directions, keeps up a constant rotary motion. It has before been shown that a helix is attracted and repelled by the poles of a battery. This suggested the principle to Ampere, that magnets owe their power entirely to currents of

electricity, circulating around the particles, and all following in the same direction. These currents flowing in the interior of the magnet, always neutralize each other, because the currents in two adjacent atoms always flow in opposite directions. There will however be left one resulting current circulating entirely around the magnet. Therefore by this theory, and the principle that currents flowing in the same direction attract, while those flowing in opposite directions repel each other, we can explain all the phenomena of magnetism; the action of all magnets by attraction and repulsion; as well as the effects of a current of electricity on a magnet. Thus if two bar magnets be brought together having the north pole of the one to the north pole of the other, then on the adjacent sides, the currents of electricity will be flowing in opposite directions, down on the one and up on the other, consequently repulsion ought to take place, and such we know to be the fact. According to this theory there there is no such fluid as the magnetic fluid. Magnetism is but the effect of electric currents. This leads us to speak of electricity excited by magnets, or — Magnetic Electricity. When a magnet is brought suddenly near to a conducting wire it excites in it an electric current. In a single wire this current is very feeble, but by coiling the wire upon itself, we may render the effect quite striking. If we connect a coil of wire with a Galvanometer, and thrust into the coil a powerful magnet, the effect will be quite sensible ~~striking~~ on the Galvanometer, causing it to deviate to the right or left according to the course of the current. If we now suddenly withdraw the magnet from the coil the needle will be deviated in the contrary direction. The effect may be increased by repeating the process. The electricity excited in this way is quite feeble & hence modes ~~have~~ of accumulating it have

been invented. Instruments for multiplying the effect are called Magneto-Electric Machines. The one constructed by Mr. Davis of Boston consists of several powerful magnets bound together, & placed either horizontally or vertically on supports and thus firmly held their places. There is an armature bent twice at right angles ~~xxxx xxxxxxxxx~~ and supported on an axis, fixed between the poles of the magnets, so that it revolves before them by means of a wheel. Around the armature are placed two coils of copper wire, insulated by silk. A needle passes through the extremity of the axis, to which the two ends of the coils, which leave the centre of the helices, are connected. A copper disc is also attached to the axis, to which the two ends of the two coils, leaving the outside of the helices joined in one, and passing along the axis, but insulated from it are attached. There is also a cup of mercury in which the copper disc is always immersed & also the needle, twice in every revolution of the armature. When the armature is made to revolve, it becomes a temporary magnet, whenever the arms carrying the helices come opposite the poles of the permanent ~~temporary~~ magnets, and when these soft iron arms ~~arms~~ have reached the points at right angles to the magnet or vertical, their magnetism is for an instant destroyed, & are as instantaneously from what they were before reaching that point. Thus by the rotation of the armature the direction of the induced current in the arms becomes changed and as often as they are alternately brought opposite the poles of the permanent magnet, which is twice in every revolution of the armature. It follows then that as often as the arms become magnetic, they induce corresponding opposite electric currents in the wire surrounding those arms, provided the circuit of the coils is complete. This it will be observed happens when both the needle and the disc are simultaneously immersed in the cup of mercury. The needle is immersed at

the time the arms are passing the poles of the magnet. Hence this is the time when the circuit is complete. It is broken by the needle passing out of the mercury, the moment the arms arrive at the vertical or neutral position. Usually two armatures are adapted to this machine; one made of very coarse wire called the quantity armature; the other made of exceedingly fine wire is called the intensity armature. They have not then the same effect.

By means of this machine, all the effects of voltaic currents may be produced. When the communication is made between the axis and the revolving disc, by means of a fine platinum wire, instead of the dipping point, the wire may be maintained at a red heat. Make the communication with an electro magnet and its armature will alternately be attracted and repelled. By using the intensity armature, and making the same connection with the hands, a shock will be felt. It will also effect chemical decompositions.

From what has been said ~~before~~ in the preceding pages, we may conclude that the agent which we call Galvanism is the same as Electricity, and this might be infered from the following reasons.

1st Each exhibits attraction and repulsion (e.g.) the dry pile

2nd Each exhibits a spark.

3rd Each gives a shock to the animal system.

4th Each may be made to charge a Leyden jar.

5th Each effects chemical decompositions.

6th Each developes heat.

7th Each developes Magnetism.

Lecture 50th Electro Magnetism

Induction. The induction of a current upon itself. Allow two poles of a feeble battery to dip into a cup of mercury. Then join them by a single wire, no spark will be seen, at least a very feeble one, But allow the junction to be made with a coil of wire, & a considerable spark will be seen accompanied with a snapping sound. This is due to the induction of a current upon itself. If we take two coils of copper ribbon, and lay one on the other & pass a current of electricity through the lower one, a current of electricity will be excited in the upper coil by induction, both at the instant of breaking and making the contact in the first coil. By attaching the upper coil to a Galvanometer, we observe that when the contact is made in the lower coil, the current in the upper coil flows in a contrary direction to that in the lower coil. The current thus excited by induction will be sufficiently powerful to magnetize a needle, if placed in a helix, and the usual phenomena of this mode of magnetizing will be exhibited. When the contact is broken or the current ceases to flow in the lower coil, the current in the upper coil flows in the same direction as in the lower.

This induced current may be made to exhibit all the usual effects of an electric current. We can obtain the spark between the charcoal points, and also the shock when it is passed through the human system. Place within a large coil of copper wire, but insulated from it, a helix of very fine wire. Pass a current through the coil, & as we have seen another current will be ~~xxxx~~ excited in the helix, made evident at the instant of making & breaking the contact in the lower coil. This secondary current excited in the second coil may be made to induce a current in a third coil, which can be made to exhibit the usual effects of

magnetizing a needle, the spark and the shock. The current in the third coil ~~xxxy~~ is called a current of the third order, & it will produce a current in a fourth coil, & this fourth a fifth & so on indefinitely. Currents have been obtained in this way as far as the seventh order, but they gradually grow feebler, & it becomes necessary to use some powerful arrangement. In all these cases, no portion of the current in the first coil passes through the second, nor any of the second through the third, for this induction may take place at a considerable distance, a foot or more. Instruments have been invented on this principle of induction, one of these is Page's Electrometer. It consists of a helix of covered copper wire, around around several needles of soft iron; two cups of mercury, in which the poles of the battery are inserted. From one of these poles the current is made to pass to a brass strap, surrounding one portion of the helix, from this it ascends to a little mercury cup, into which dips a wire, along which the current passes to a second mercury cup, through this to a second brass strap, which communicates with one portion of the helix. The other end of the helix communicates with the other mercury cup, & consequently with the other pole of the battery, & thus the current is complete. The wire which conducts the current from strap to strap is movable & arranged so that one end of it is curved & allowed to suspend before the needles of soft iron. When the circuit is complete these needles become magnets, & attract the end of the wire near them. But this causes the other end, which dips in a cup of mercury and thus conveys the current, to emerge from it, thus the circuit is broken. Now the needles are no longer magnets, & this end of the wire will therefore fall into the cup by its own weight. Then the circuit will again be complete & the needles will attract the other end of the wire & the circuit will again

be broken. This will continue as long as the coil connects with the battery. Now around this coil of coarse wire is wound a coil of very fine wire, & as the current passes through the coarse wire, a current is ~~xxxxx~~ induced in the fine wire, which may be made very sensible by connecting the two ~~xxxx~~ coil with the hands. A Leyden jar can be charged with this instrument.

Electro Magnetic Machine. The first magnetic machine proper was invented by Prof. Henry in 1831. It consists of a bar of soft iron, wound around with copper wire, for the purpose of inducing magnetism, for as soon as the current passes through this helix, it becomes an electric magnet. Immediately beneath the ends of this magnet, are placed two permanent magnets, with their North Poles upward. Now when the current passes through the helix, the electric magnet thus produced, with its south pole is attracted by one of the permanent magnets, while its North pole is repelled & the whole machine is lifted on one side, in which position it would remain, unless some counter influence draw it to the other side. This helix, it must be mentioned, is balanced in its centre on an axis. In order to accomplish this the polarity of the magnet must be reversed, & in order to keep up the motion, the reversal must be constant. This is effected as follows, to each end of the helix is soldered a short piece of bent wire so as to form as it were two terminations for the coil at each end. Immediately beneath the ends of these wires are two batteries, into the poles of which these ends dip just when either side is depressed. Now by this contrivance when the current passes through the helix, the South pole of the electric magnet is attracted so that the ends of the bent wire, fall into the cups of ~~xxxxxx~~ the battery, & thus completes the circuit. Immediately the quasi South pole becomes a North pole & is repelled by the North pole of the permanent magnet, which forces the other side down in connection with the other battery; when immediate

ly the reversal of the poles again takes place, & thus the operation goes on continually & an oscillating motion kept up. In this machine it is not necessary to have two batteries. The four mercury cups may be so attached to a single battery, as that the poles may be reversed in the same manner as before. As soon as Prof. Henry made known his discovery, various modifications of his machine were proposed. The first important one was that of Prof. Ritchie for converting the reciprocal motion into a circular one. It consists of an electric magnet supported on a pivot, so as to revolve freely. The two ends of the coil slightly dip into a vessel containing mercury, which is divided into two parts by a wooden partition. Each partition is in connection with a pole of the battery. Two permanent magnets are placed near for the purpose of attracting & repelling the moveable one. When the electric magnet is placed at right angles to the plane of the fixed magnet, one pole is attracted & the other repelled, so that it is turned round a portion of its revolution. Its momentum causes it to complete the semicircle, & past them the partition between the two poles is reversed so that the ends of the coil change places, & the polarity of the magnet is changed. This causes it to be attracted to the opposite side; the momentum causes it to complete the semicircle, & then again the same reversal takes place. This rotary motion will be kept up as long as the operation of the battery continues. This machine was soon found to be of little use, for the ends of the wires scatter the mercury & thus the rotation is often impeded. Prof. Page has still farther improved the preceding inventions in several ways. One is the Vibrating Armature machine. It consisted of a small electro magnet, and the armature so mounted as to have an ~~[illegible]~~ oscillating motion. When the communication was made with a battery, this motion would ensue. Davenport revolving magnet is another contrivance for producing motion by a current.

It consists of a fixed magnet arched and a second moveable one which may revolve within the first, both being electro magnets. When the current pass es through both, and the moveable one is placed at right angles to the other, one side is repelled & the other attracted by the two poles of the fixed magnet, which causes the moveable magnet to revolve one half a revo= lution. The poles are then reversed by means of springs before described, which form the connection with the poles of the battery, and by this means the motion is kept up.

Page's revolving armature is another instrument invented by him. It consists of an electro magnet, and an armature of soft iron, suppor ted so as to revolve about a vertical axis. We have alternately Magnetism and no magnetism. There is in this no reversal of the poles.

# Lecture 51st

Page's Reciprocating Armature Engine consists of two electro magnets of the form of horse shoe, placed parallel to each other turned upward. Upon them there is a double armature, one on each magnet, and connected together. Each part of this armature will only be attracted when the current passes through the magnet beneath it, and if the current pass through the two magnets alternately, motion will be produced in the armature. To the two armatures is attached a working beam, which works a crank, that is attached to a fly wheel

R H Simmons